Psychotextiles and their Interaction with the Human Brain

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Thesis submitted for the degree of Doctor of Philosophy

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May 2016

ABSTRACT

This work crosses the boundaries between design and technology, and it focuses on pattern design, its relationship with neuroscience and how new SMART products can be developed from this interaction. What we see in our environment has significant influence on our emotion and behaviour. A simple shape and form is able to impact on our emotions. This research has explored the emotional effect evoked by different visual pattern characteristics. Two paired pattern categories were investigated: repeating/non-repeating and weak/intense. Repeating patterns contain regularly repeating elements and have symmetrical and continuous features; in contrast, non-repeating patterns contain irregularly repeating elements and have asymmetrical and discontinuous features. Weak patterns are faint, light and simple compared to intense patterns that are high in contrast, bold and complex. The emotional response to each type of pattern was investigated directly by brain and cardiac activities of twenty subjects by electroencephalography (EEG) and electrocardiography (ECG) measurements and by self-evaluation; the former is used to measure the brain wave activity, and the ECG to analyse the heart rate changes. These physiological signals were then analysed, interpreted and correlated with people's self-evaluation of their emotional response to the pattern. It was found that repeating patterns produce a more pleasant sensation than non-repeating patterns, and intense patterns evoke a higher level of excitement than weak patterns. The significant changes in the emotional effects found by changes of pattern and the good correlation of the objective and subjective emotional measurements encouraged the implementation of pattern change by design and production of SMART fabrics. Four knitted fabrics with the ability of switching their pattern appearance from repeating to non-repeating, and from weak to intense have been successfully produced with a purpose made electrochromic composite yarn. The emotional effects of pattern-changing of these fabrics have been further investigated. The notion of influencing human emotion by engineering the pattern design and characteristics of SMART textiles is established and these fabrics are named Psychotextiles. Finally the event-related potential (ERP) investigation of the visual brain (no thinking, or memory) revealed that there may be an influence on human emotional effects in less than 1 second from the time of seeing the object; a time sufficiently short for these to be little analysis within the brain.

ACKNOWLEDGEMENTS

Firstly I would like to express my gratitude to Professor George K. Stylios for his expert guidance, supervision, and positive encouragement throughout the duration of this work. Many thanks are also due to the technicians of the Heriot Watt University School of Textiles and Design, for their assistance in the knitting and weaving workshops at the campus in Galashiels.

Special thanks go to my husband, my parents, and also extended family and friends for their support. Lastly I must give kind thanks to everyone who volunteered to take part in my experiments, the results of which would not have been possible if they had not agreed to give up their own free time.

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TABLE OF CONTENTS

TERMINOLOGY

Term	Definition
Repeating pattern	Repeating pattern is a pattern that contains regularly repeating elements and has symmetrical and continuous features.
Non-repeating pattern	Non-repeating pattern is a pattern that contains irregularly repeating elements and has asymmetrical and discontinuous features.
Weak pattern	Weak pattern is relatively faint, light and simple compared with intense pattern.
Intense pattern	Intense pattern is relatively high in contrast, bold and complex compared with weak patterns.
EEG	Electroencephalogram is "*a measurement of electrical activity generated by the brain and recorded from the scalp"*[1, p814] .
ERP	Event-related potential is "*a measure derived by averaging EEG responses to stimuli"* [2, p16].
EOG	Electrooculogram is "*a measurement of electrical activity produced when the eyes move"* [2, p16].
ECG	Electrocardiogram is "*a recording of the electrical potentials generated by the heart"* [2, p436].
SAM	Self-Assessment Manikin (SAM) is a rating system for assessing people's emotional response to a given stimulus [3, 4].
PAD	Pleasure-Arousal–Dominance (PAD) Emotional-State Model is three essential dimensions that describe various human emotion: pleasure-displeasure, arousal-nonarousal, and dominance-submissiveness [5].
EEGLAB	EEGLAB is "*an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis"* [6].
KARDIA	KARDIA is "*a software for the analysis of cardiac interbeat intervals*" [7].
LED	Light-emitting diode (LED) is a semiconductor device, which emits light when a suitable electric potential is supplied [8].
EL	Electroluminescence (EL) is "*a material emits light in response to the passage of an electric current or to a strong electric field"*[9].

CHAPTER 1 INTRODUCTION

In the last decade, the development of SMART textiles has enabled researchers to explore new ways of interaction between textiles and users. Colour, pattern and shape-changing effects can influence our emotions and moods. For example, Stylios developed a concept of SMART ambience with mood changing textiles [10], as seen in Figure 1-1. SMART technologies such as shape memory materials, colour-changing dyes and wearable electronics are optimised to create colours, patterns and texture changing effects on textile materials. There is increasing interest to construct SMART structures, systems and prototypes with tailor-made functionality and aesthetics, which can react continuously to the emotions of the user, by monitoring his/her voice for example [11]. Recognising the convergence of textiles, electronics, and information and communication technologies, Bruner proposed three design scenarios of interactive textiles in which the wearer expresses emotions and moods by sending messages or using the changes of the SMART fabric in clothing, and the recipient receives the information through the changes of a visual display or directly by the changes of his/her SMART clothing [12]. Bruner explained that in these scenarios the sender can either let the recipient understand his/her feeling by changing the colour of the clothing. Stead developed a concept of an “Emotional Wardrobe” [13], in which clothing is able to represent and stimulate the wearer’s emotional responses. As seen in Figure 1-2, the garment is equipped with sensors and interface technologies. The wearer’s physiological signals are recorded and sent to a computer wirelessly to determine the wearer’s emotional state. Then, according to a pre-defined aesthetic desire of the wearer and his/her corresponding emotional state, the garment will change its appearance.

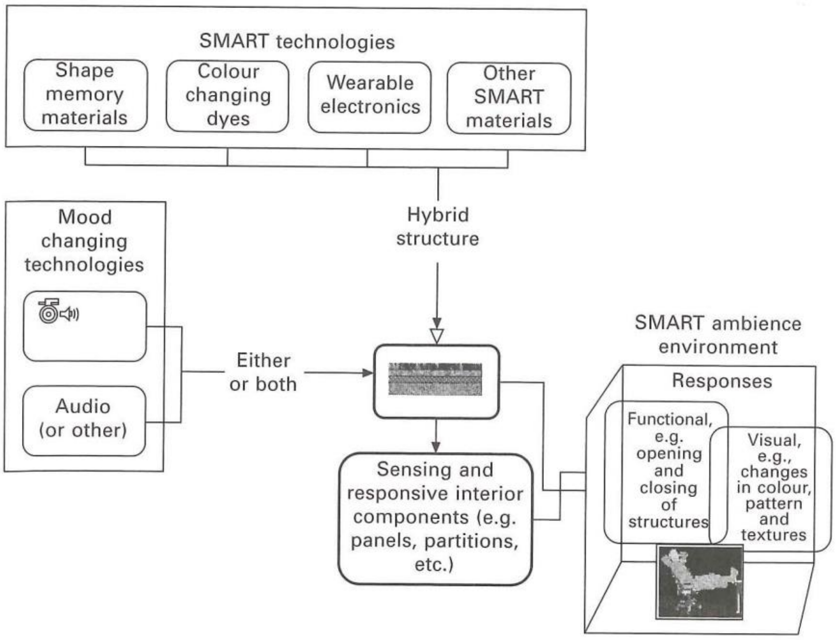


Figure 1-1 Combining mood-changing technologies with smart technologies for the development of a SMART ambience.[10]

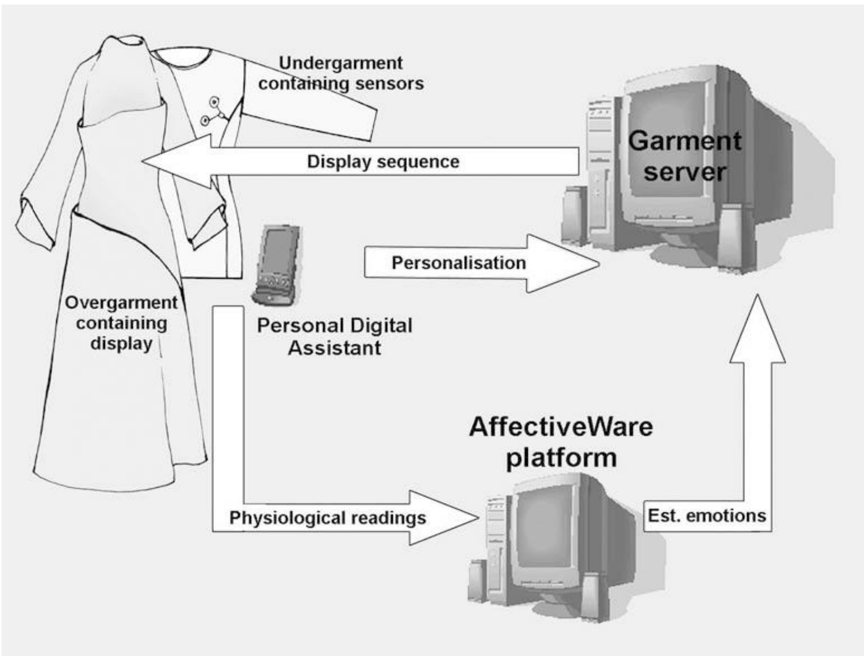


Figure 1-2 Emotional Wardrobe.[14]

Working prototypes have been built to demonstrate how SMART textiles and clothing can interact with users' psychological states. For example, Philips had developed two futuristic garments that can represent the wearer's emotional state [15, p120, 16], as shown in Figure 1-3. The dress on the left is named "Bubelle", also known as the "Blushing Dress", and the dress on the right is named "Frisson". Both garments can measure the wearer's bio-signal from the skin using biometric sensing technology. The signal, through electronics, controls the light emission of the garment, so that the illuminated patterns simulate the wearer's real-time emotional state and also send the information to the surrounding space around the wearer. Another fashion design is named "GER Mood Sweater", developed by design studio Sensoree [17]. As seen in Figure 1-4, the garment can interpret the wearer's excitement levels by showing different colours on the collar through the assembled light-emitting diode (LED). Sensors are placed on the wearer's hands to record the electrical activities on the skin, and the recorded bio-signal is then translated into specific colours associated with different excitement levels. Yang also designed an emotional interactive garment range for men and women named "Moodwear" [18], as shown in Figure 1-5. The main garment is made with scattering electro-luminescent fibre optic fabric. It can detect and analyse the wearer's voice characteristics (tone, amplitude, rhythm) that can indicate the wearer's mood state according to psychometric charts, by using bespoke electronics carefully embedded in the garment. This information will then trigger an appropriate colour change in the fabric in order to change the wearer's mood. Hence, "Moodwear" can understand the wearer's emotion, but also has a direct effect on his/her emotion. Another high-tech design is the "Synapse Dress", a 3D printed bodice and a headset developed by Wipprecht [19], as shown in Figure 1-6. This dress can monitor the wearer's brain wave and heart rate activities through electrodes that are embedded in the garment. LED lights on the bodice will flash and glow in different orders to indicate the wearer's stress and attention levels. Measuring an individual's psychological state through his/her brain wave activity is an advanced technology. However, no evidence has been found of how Wipprecht achieved this technology in his design. A similar design is the "Happiness Blanket" designed by British Airways [20], as shown in Figure 1-7. Passengers are wearing headbands that measure their brain activity to determine their stress levels. Through Bluetooth, the data are sent to the blanket every second. The optical fibre woven into the blanket will then glow from a red colour to a blue colour depending on the passenger's mental state changing from being stressed to being relaxed. British Airways claims that the "Happiness Blanket" allows them to see passengers' mental experience during their flight. However, no scientific document that explains the technology of the "Happiness Blanket" can be found. Bowker's project named "Eighth Sense" [21] also showed a responsive textile sculpture that reacts to the user's brain activity seen in Figure 1-8. The sculpture is made out of hundreds of fins painted with thermochromic colours. In her presentation, she put on a headset with electrodes and her brain wave is then measured in a computer and interpreted to a command to trigger a colour change on the surface of the sculpture. Hence the displaying colours of the sculpture are claimed to simultaneously respond to her brain activity. Bowker suggests that different colours could be used to present different mental states; for example, red colour indicates anger or anxiety, while blue colour reveals a sense of calm. Again, there is lack of evidence of the technology background of Bowker's work except a showing of a demonstration video.

Figure 1-3 Bubelle (left) and Frisson (right).[16]

Figure 1-4 GER Mood Sweater.[17]

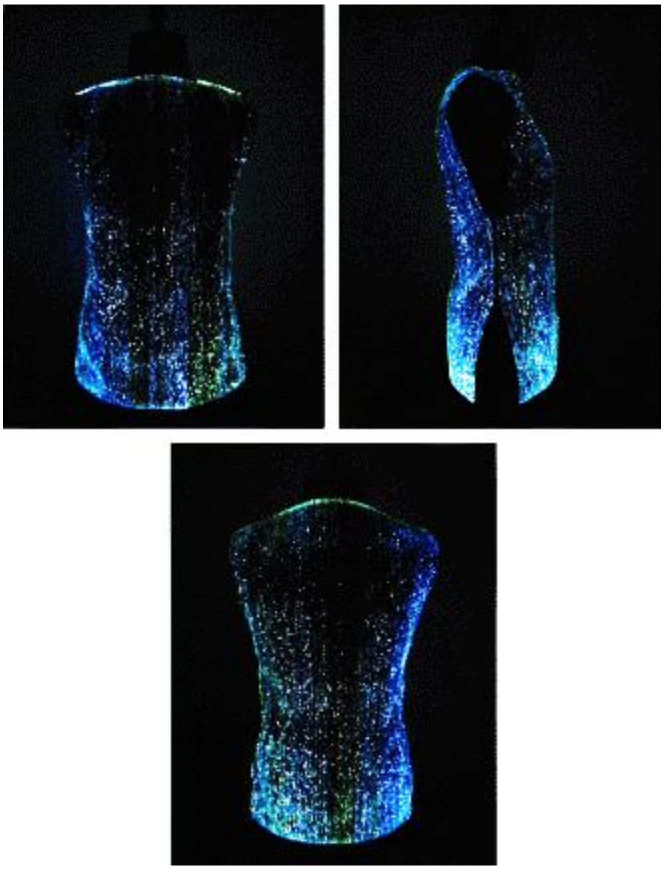


Figure 1-5 Moodwear.[11]

Figure 1-6 Synapse Dress.[19]

Figure 1-7 The Happiness Blanket.[20]

Figure 1-8 The Eighth Sense.[21]

Textiles responsive to human brain activity is a cutting-edge concept in textile design and psychology. Whether conceptual frameworks or working prototypes shown once and without being able to determine their construction and working characteristics, the given examples show a trend of innovations using SMART textiles and clothing that relates to users' psychology. Sensor networks are embedded inside garments to detect skin conductance, heartbeat and voice, and most importantly try to interact with the brain activity, to determine the emotions of the wearer. Electronics and information technologies are employed to acquire these signal data and interpret them into corresponding colours in the garment through LEDs, thermochromic dyes or optical fibres. The interface of psychology with design is a new and emerging research area which is now advancing rapidly due to the capability of SMART fabrics and wearable low-energy wireless electronics. Most of these designs however including the scarce systematic research mainly focus on the capability of exploring what SMART fabrics and attaching sensors on what garments can do, which by default can affect our emotion and not how they can be designed to actively influence our emotions. Can we design to influence a specific human emotion, if so can we develop textiles that can influence our brains to change from one psychological state to another by their SMART functions? We named these SMART psychologically interactive textiles and clothing "psychotextiles" and aim to answer these questions in this study.

Psychologists over the years have found that our mental state and behaviours can be significantly influenced by our stimuli and particularly by what we see, such as art works, colours and patterns, as further discussed in Chapter 2, section 2.1. These findings show clearly that colours and patterns can affect emotional state. Colours and patterns are the most predominant abilities of SMART textiles. This research focuses on the influence of pattern in the brain and investigates the psychological effectiveness of pattern-changing functionality of SMART fabrics. Physiological studies of pattern perception have found that some patterns can cause negative effects on human physiological well-being. Some features of pattern such as shapes, forms, angularity, sharpness and symmetry have been found to have significant effects on a viewer's response and trigger specific emotional responses. However, the patterns used in these studies are only indicative, limited and not practical for using in everyday living.

This study starts with an investigation of the brain in relation to specific pattern attributes using an electroencephalogram (EEG) with 19 recording electrodes, so that many areas of the brain activity can be established. This methodology is based on Psychophysiology, which is studying a human's psychological manipulations and their corresponding physiological activities, which is described in Chapter 2, section 2.2. The brain plays the most important role in determining our being, in our understanding of our world and in our decision processes. Therefore, directly measuring the brain activity gives a thorough examination of our response to an external stimulation. EEG is used in this research to measure the brain activity, and the five frequency bands (Delta, Theta, Alpha, Beta and Gamma) of the EEG signal are analysed and interpreted in relation to the emotional response of 20 subjects when viewing specific patterns. The frontal EEG asymmetry model is employed to assess subjects' approach/withdraw-related emotional experience when responding to these patterns, and the event-related potential (ERP) technique is applied to measure the impact of the pattern on the visual brain where the visual information is processed. These measurement and analysis techniques are described in Chapter 2, section 2.4. At the same time, the heart rate changes of each subject when responding to the pattern stimulus is also measured, interpreted and compared by using the electrocardiogram (ECG), and related to their emotional response. The ECG measurement and analysis techniques are described in Chapter 2, section 2.5. Conjoining with the objective measurements of brain activity and heart rate changes, subjective evaluation is also used by the Self-Assessment Manikin (SAM) system for assessing viewers' emotional responses to the pattern stimulation, and the 9-point hedonic scale for assessing viewers' personal preference to the patterns. The description of these two systems is in Chapter 2, section 2.6. The combination of objective physiological measurements and subjective evaluations can provide precise information on how humans respond to different patterns.

This research had explored the differences of the emotional influence between repeating and non-repeating patterns, and between weak and intense patterns. These patterns are seen in our environment and have been decoded in photography and art by artists, and can be developed in textile fabric designs. Repeating pattern is a pattern that contains regularly repeating elements and has symmetrical and continuous features. Contrastingly, a non-repeating pattern is a pattern that contains irregularly repeating elements and has asymmetrical and discontinuous features. Differences between the pair of weak and intense patterns are that weak pattern is faint, light and simple; whilst intense pattern is high in contrast, bold and complex. In order to find out how such variations in a pattern could impact on viewers' responses, this research carefully selected the representative samples of each type of pattern, designed and conducted controlled experiments, in which participants are exposed to these samples whilst recording their EEG and ECG signals. The corresponding EEG and ECG signals of each sample were then analysed. The subjective evaluation of emotional response and preference for each sample were also carried out. Participants' responses to the two paired patterns were then compared and the mean of their difference was calculated by using a statistical hypothesis test and confidence interval estimation. Significant differences observed in the experiments were then analysed and interpreted in relation to viewers' emotional responses, so that the difference between the effects evoked by the two paired patterns are established. The details of these experiments are reported in Chapter 3.

Having established these paired patterns' affecting emotions, we went on to actively design psychotextile fabrics that generate specific emotions by switching their pattern. In order to achieve the properties of these patterns, a new SMART colour-changing electrochromic composite yarn was developed. This composite yarn was used in both knitting and weaving processes to produce fabrics that can change patterns from one to another. The pattern-changing effect of the fabrics is investigated. Finally, new designs of pattern-changing fabrics were carefully produced, in accordance with the results of Chapter 3, which pattern-changing effects require regularly to irregularly repeat, symmetrical to asymmetrical, light to bold, and simple to complex effects. The production of this SMART composite yarn and fabric patterns with the changing effects are reported in Chapter 4.

In Chapter 5, experiments were conducted to verify the pattern-changing effect of psychotextiles on viewers' responses, using the same tools as described in previous chapters. Comparison of brain wave responses, heart rate changes and subjective evaluations between the two patterned appearances of each fabric and interpretation of the differences in relation to emotion, the verification of emotional effect causes hypothesised when these fabrics were designed to establish the notion of actively designing emotions in SMART textiles and hence establishing their name as psychotextiles. Visual ERP evoked by the pattern-changing effect is also investigated in this section. Using the ERP technique, the impact of each patterned appearance of the fabric on the visual brain is measured. By analysing and comparing the components of the ERP, the visual response evoked by each pattern change of fabrics is revealed. Of course, the implications of our findings go beyond textiles in psychology, in art, in film, in advertising, in marketing, in our environment and in our well-being. These discussions are made in the final Chapter 6.

CHAPTER 2 LITERATURE REVIEW

2.1 The Influence of Art, Colour and Pattern to Human Emotion

Is it possible to influence an individual's feelings or moods by a visual stimulus? How significantly can our body and mind be affected by what we see? Studies in the application of art works in a clinical environment give interesting answers. For example, adult patients undergoing flexible bronchoscopy reported better pain control, when they are viewing paintings and listening to sounds of nature [22]; breast cancer patients showed less anxiety during chemotherapy treatment when viewing images of deep sea [23]; patients with burns experienced less pain intensity and lower levels of anxiety during their dressing changes by watching videos of scenic beauty accompanied by music [24]; and in the waiting area of emergency departments, people had significant reduction of restlessness, noise level and staring at other people when pictures or videos of nature were shown [25]. Therefore, we know that visual stimuli have an impact on people, which can lead to different physical well-being and behaviour.

Colour and pattern change are the most predominant abilities of SMART textiles. Can we use these two features to create an active interaction with human emotions in real life? The influence of colour has been studied for some time by Psychologists. Early studies have shown that colours can affect human physiology by means of muscular reaction, blood pressure, heart rate and brain waves. Patients with Parkinson's disease or when brain-damaged tended to get worse in their pathological condition when exposed to red colour, but improved under green colour [26]; people's blood pressure and pulse increased in a red room and declined in a blue room [27]; therefore red light was more arousing than blue light on visual cortical activity and the functions of the autonomic nervous system [28]; people associated red light with anxiety, whilst blue and green lights with a calming feeling of relief [29]. Arousal and excitement by red colour is also found when compared with groups of green and blue colour [30, 31, 32, 33]. Other properties of colour were also found to impact on people's psychological response, for example, strong colours give people a sense of excitement, while weak colours in the same environment give people the impression of calmness [34]. The chromatic strength therefore is more significant than its hue in affecting people's level of arousal [35].

The influence of pattern on human emotion has also been investigated. Clinical observations have shown an interesting effect of pattern on people's responses. For example, 82% of migraine suffers reported to experience a migraine after looking at a striped gratings pattern; most typical stripes or grating patterns can induce seizure on the patients who have pattern-sensitive epilepsy; and schizophrenics and Parkinson patients have greater sensitivity to verticality, wavy patterns or flickering lights. Another study in a real life environment has shown that a geometric chevron pattern carpet induces a feeling of being on an undulating surface, such as a sea wave. In another study, shirt makers working on fabrics with blue and white pinstripes reported to having symptoms of eye strain and fatigue with incidences of nausea and headaches. A study of the influence of stripe and checkerboard patterns in living-space using behaviour mapping has revealed instances of displeasure, avoidance behaviours, expressions of anxiety, and negative comments with the stripes and distraction, feelings of movement and vibration with the checkerboard. No participant was comfortable with patterns on all four walls. In another interior space experiment conducted when a dotty pattern was put on the wall of a music-rehearsal room at a performing arts hall, performers found that the wall appeared to move and that it had a "swimming effect", which led to perceptions of fatigue and annoyance. [36]

Patterns are more diverse and complex compared to colours, which makes it more complicated to categorise them. It may be the reason why studies of pattern influence are rare. Nevertheless, in studies of pattern perception, researchers are now finding that some features of pattern form and shape have significant impact on our response. These findings are reported as follows.

2.1.1 *Shapes*

In an earlier study, researchers have found that different shapes have different levels of impact on viewers' visual brain responses, and this impact is more significant than the size of a stimulus [37]. The visual brain locates at the back of the cerebrum and is the centre for processing the visual information [1, p314-347]. Within a checkerboard, a horizontal grating, a set of concentric circles and a set of radial line patterns, the checkerboard has been found to be the most effective pattern that evokes the largest visual brain response [38, 39, 40]. An investigation of the effects between a triangle, a square and a circle has shown that the triangle shape has the strongest impact on the visual brain [41]; and a similar result showed that an upright triangle, an inverted triangle and a diamond shape have larger effects than a square and a circle [42]. People's emotional experience also can be alerted by a simple shape. A downward pointing V shape has been found to trigger a perception of threat. Downward pointing tringles, upward pointing triangles and circles were compared in an assessment of the association with pleasant, unpleasant and neutral emotional response. The downward pointing triangles were found to be categorised faster as unpleasant in response than as pleasant or neural [43].

2.1.2 *Corners and Angles*

A pattern containing a sharp corner has been found to have a significant effect on people's visual responses. A study of visual response to herringbone patterns that have different angles at 135^o, 90^o and 45^o, and contain sharp and rounded corners shows that sharp cornered patterns triggers a quicker response from viewers than the rounded pattern; and the pattern with 90^o corners generated the largest response, the one with 45^o corners next and the one with 135^o corners the smallest [44]. However, another study found that the largest response was evoked by the pattern with 45^o corners instead of the 90^o corners [45]. Although the difference between the visual effect of 45^o and 90^o corners remains unclear, both studies have showed that the pattern with straight lines evokes the smallest response compared to the one with angles.

2.1.3 *Size*

Checkerboard patterns at different check sizes have been studied. The size of the check was measured by the visual angle, that is determined by the size of an object and its distance from the eyes of the viewer, with distance fixed. The smaller size of the objects produce a smaller visual angle. Studies showed that the checkerboard pattern with a smaller size of check evokes a larger response from the visual brain [38, 46]. However, this finding is limited to the check size of a checkerboard pattern, and it is unclear that if it is generic for other shapes or forms.

2.1.4 *Noise*

The noise of a pattern is caused by different levels of sharpness and blurredness. Researchers placed a black and white checkerboard pattern in the front and the back of a translucent screen to obtain different levels of noise, and compared viewer's responses to these two conditions. They found that the sharper checkerboard pattern causes larger response in the visual brain, while the blurred pattern decreases the response [46]. However, there is a lack of research for supporting this finding.

2.1.5 *Complexity*

Four categories of complexity of a pattern including irregularity of arrangement, amount of material, incongruity and random redistribution have been found to have effect on viewers' responses. The higher the level of the complexity produced by these four categories evokes higher arousal in the brain [47]. A further study has found that only increasing the number of elements in a pattern can increase the arousal level of the brain [48]. There is no up-to-date research to verify this finding. On the other hand, researchers found that over stimulating environments with complex or incongruous visual patterns increase emotional feelings [49].

2.1.6 *Symmetry*

The effect of symmetry and asymmetry has been found in both animals and humans. Many animals are sensitive to bilateral symmetry and have innate preferences for symmetrical patterns [50, 51, 52, 53]. For example, bumblebees prefer symmetrical stimuli when searching for food. Studies of the attraction of the human face have showed that face symmetry has a positive influence on attractiveness [54, 55]. Another study has found that a symmetrical pattern is more easily detected and processed by the human visual system compared to an asymmetric pattern [56]. Most studies of symmetry are associated with preference and aesthetic judgement. Study of its emotional influence is scarce.

Despite lack of studies, there is a clear indication that patterns have influence on human psychology and physiology. Some features of pattern have been effective in viewers' brain responses. These patterns were simple and part of psychological tests, compared with the patterns used in practice, and some studies only used subjective analysis and not brain or heart objective measurements. Also, the patterns in previous studies are presented on either paper or computer screen, which is far from the reality of the actual pattern effect and none have used real fabrics. Therefore, although previous work helps to formulate our thinking, their findings are neither complete nor conclusive. The need for a systematic study using a combination of data by objective measurement on the brain and heart activity and subjective measurement by self-evaluation can reveal interactions and effects that will allow us to establish materials that can be purposely designed to interact in a predefined way with our emotions. In this work, these materials are SMART textiles called psychotextiles. The implication of our findings would be in new knowledge of the effects of pattern in neuroscience, creating know-how in designing materials such as textiles which actively interact with our emotions by virtue of their design and finally to join in the wider philosophical discussion about art, creativity and free will.

2.2 Applications of Psychophysiology in Design

Measuring the brain activity for understanding an individual's psychological state is originated in psychophysiology, which is a branch of psychology studying "*the relations between psychological manipulations and resulting physiological responses, measured in the living organism, to promote understanding of the relation between mental and bodily processes [2, p2]".* The physiological responses include brain activity, heart response, skin conductance, muscle activity, changes in the pupillometry, eye movement, blood volume, and blood pressure. Psychophysiological findings provide the physiological base of understanding psychological processes like emotion, sensation, perception, and attention.

In recent years, knowledge of psychophysiology has started to be applied in the research of a human's aesthetic perception and in aspects of affective design. For instance, a novel interdisciplinary research field is named Neuro-aesthetics, in which subjects' brain activity is measured when viewing or interacting with different aesthetic stimuli like paintings, music, and art, and it aims to investigate the correlation between the brain activity and human aesthetic experience [57]. In Kansei engineering, researchers use questionnaires in conjunction with physiological measures to evaluate a user's responses to specific design, which '*aims to develop such a product that people want to have deeply in their mind'* [58, 59]. In marketing research, researchers have started to measure customers' brain activities and other physiological responses to various advertising stimuli, in order to understand the neurological correlation with consumer behaviour. This research field has been named Neuromarketing [60]. In computer science, psychophysiology is optimised in the development of Affective Computing which is the *'computing that relates to, arises from, or deliberately influences emotion'[61, p3]*. Application of psychophysiology has also been seen in webpage design [62], media design [63] and interior design [64].

In the textiles and fashion aspect, there are very few researches that involve psychophysiology in their study. In Japan, Naitou et al. assessed the influence of the display and colours of clothes of a dressing up image on viewer's responses by using a semantic differential method and by measuring their cardiac activity and galvanic skin response [65]. Yukie et al. investigated the colour influence of comfort in clothing based on participant subjective evaluation and the alpha frequency band of their brain wave responses and the fluctuations in their heartbeat when wearing the cloth with/ without looking at the mirror [66]. Chinen et al. compared participants' feelings on wearing two types of one-piece dress by measuring their brain waves and determining their subjective judgments in order to study the comfort of the garments [67]. Horiba et al. proposed an evaluation method to assess the wearer's tactile sensation by measuring the evoked response from their brain waves [68]. Miyatsuji et al. conducted a study on the effect of skin pressure of clothing produced by a conventional brassiere and a newly designed low skin-pressure brassiere. They measured the power spectrum of participants' heart rate variability and found significant negative impact of the conventional brassiere on the wearer's autonomic nervous system [69]. There is one study on the pattern effect by Kato. She measured participants' brain waves and heartbeat to determine the exciting and clamming effects of different patterns on a simple dress [70]. However, the patterns used in Kato's study are limited and restricted in a garment shape that are drawn and presented by computer graphics. Therefore, Kato's findings of pattern effects might be not generic for other application.

2.3 Assessment of People's Emotional Response

In the perspective of cognitive neuroscience, emotions are *"specific and consistent collections of physiological responses triggered by certain brain systems when the organisms represent certain objects or situations (e.g., a change in its own tissues such as that which produces pain, or an external entity such as a person seen or heard; or the representation of a person, or object, or situation, conjured up from memory in the thought process)"* [71, p15]. There are basic emotions: joy, distress, anger, fear, surprise and disgust that are universal and innate in our human being. They are not learned and not different from culture to culture, just as part of human nature. And, there are higher cognitive emotions, which are also universal but have more culture variation. They include love, guilt, shame, embarrassment, pride, envy and jealousy [72, p1-21]. Psychophysiologists consider emotional acts and their effects by measuring biological phenomena. They report that our emotional experience seems to lie within a black box with three dimensional outputs, from which the emotional state can be specified. The three dimensional outputs are the behaviour, language and physiology. Each of them contains different measurable representative responses. The behavioural outputs include the defining survival actions or their variants such as approach, avoidance, attack, or threat display. The language outputs include expressive communication such as distress cries, verbal attack or changes in voice intensity and frequency, and evaluative reports like descriptions of feelings and attitudes or self-rating. The physiological outputs involve changes in the viscera and the somatic muscles, facial muscle patterns, respiration, endocrine and immune system, and brain activities. The measurement of emotion is suggested not to limit the assessment on one single output, like the traditional subjective method that is only based on self-reporting [73].

The present research assesses the viewer's emotional response to designed patterns through physiological and language output. The physiological output is observed by measuring the brain wave and heart rate activities; the language output is through the self-evaluating reports obtained by using the Self-Assessment Manikin (SAM) affective rating system and the 9-point hedonic scale. Each of these measurement tools is described as follows.

2.4 Measurement of the Brain Activity

2.4.1 *Electroencephalogram (EEG)*

The brain plays an important role in the performance of our body and mind. Inside the brain there are three parts; the cerebrum, the cerebellum, and the brain stem, as shown in Figure 2-1. Each of them has vital functions. The cerebrum, which is the largest part of the brain, is responsible for sensations, perceptions, voluntary movement, learning, speech and cognition. The cerebellum is located behind the cerebrum and connects with the spinal cord. It is much smaller than the cerebrum but plays an important role in the control of the body movements. The brain stem connects the cerebrum and the spinal cord and is responsible for the regulation of breathing, consciousness and the control of body temperature [1, p167-168]. In the anatomy of the brain, each hemisphere of the cerebrum is divided into 4 lobes: Front, Parietal, Temporal and Occipital; and the Central sulcus lies in the borders between the Frontal and the Parietal lobe, as shown in Figure 2-1. Each of these lobes has specific functions.

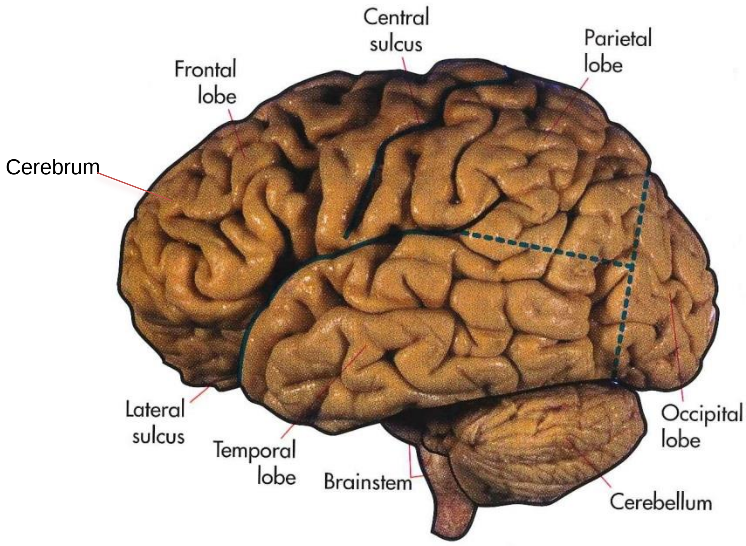


Figure 2-1 The left lateral surface of the brain [74, p1].

Every function of the brain is made up by billions of brain cells interacting and performing together. A brain cell is called neuron. It is the basic functional unit of the brain. The interaction between neurons is based on transmissions made by electrical signals and chemical reactions. When a large number of neurons have synchronised activity, electrical potential is generated, which can be detected by placing electrodes on the surface of the scalp, amplified and conditioned to provide useful data. Recording the electrical potential over time gives a wave form trace called Electroencephalogram (EEG) or Brain wave, a typical sample of an EEG is shown in Figure 2-2 [1, p607]. Two EEG traces are recorded from electrodes T4 and Cz and electrodes Cz and T3. The signals are amplified and conditioned and saved in file or drawn on a roll of paper by a pen recorder. The use of an EEG offers a non-invasive method for inspecting the brain activity. Psychophysiologists use EEG data to discover the relationship between the brain activity and specific human behaviour, such as motor performance, mental activities, sensation, attention and perception.

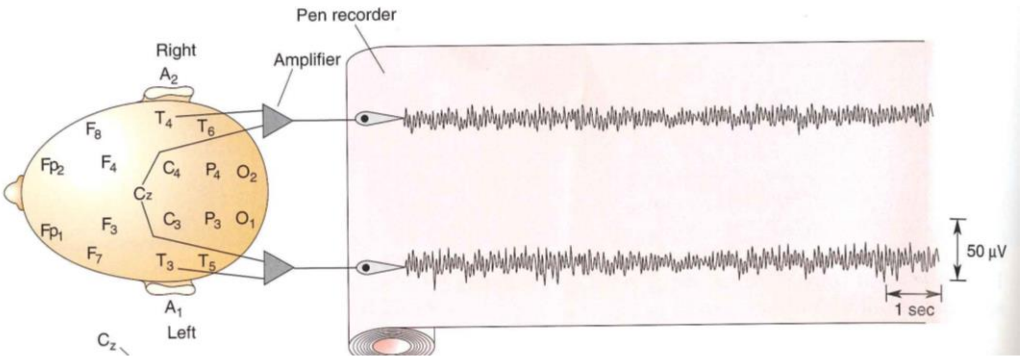


Figure 2-2 Typical EEG signals [1, p608].

2.4.2 *EEG frequency band power*

The EEG signal contains various rhythmic patterns. Some are large and slow waves; others are small but fast waves. Five typical EEG waves are observed from the human brain, which are the Delta wave, Theta wave, Alpha wave, Beta wave and Gamma wave. Each of them has a specific frequency and amplitude. The Delta wave is the largest wave with an amplitude between 20-200 µv, but has the lowest occurring frequency at less than 4 Hz. The Theta wave has an amplitude between 20-100 µv and frequency between 4-7 Hz. The Alpha wave is the most commonly recorded in a human EEG. It has a frequency at between 8-13 Hz and an amplitude of about 20-60 µv. The Beta wave is a relatively faster wave occurring at 14-30 Hz frequency with an amplitude of around 2-20 µv. The Gamma wave is the smallest and fastest wave, which occurs at over 30 Hz and its amplitude is approximately between 5-10 µv [2, p66-70]. There are examples of the Delta, Theta, Alpha and Beta wave shown in Figure 2-3.

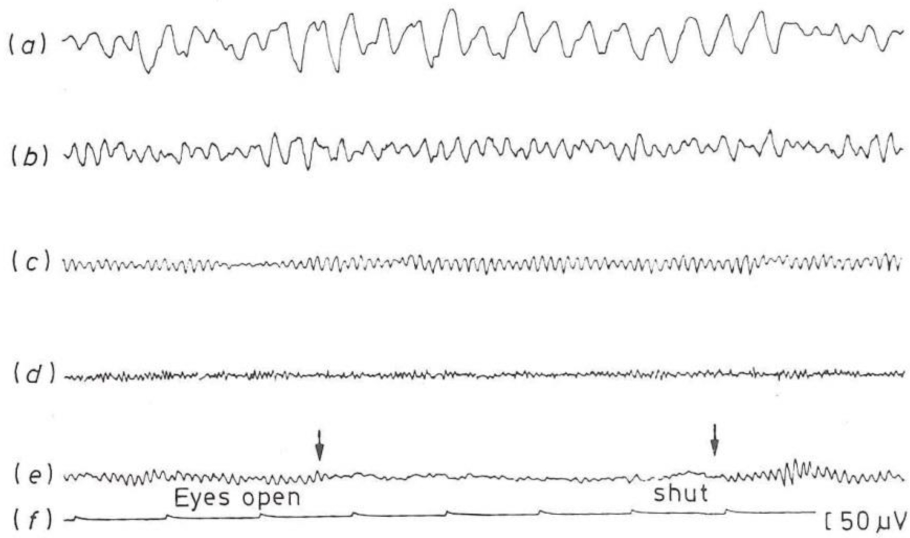


Figure 2-3 Examples of (a) Delta wave, (b) Theta wave, (c) Alpha wave and (d) Beta wave, (e) Blocking of the Alpha wave by eye opening, (f) 1s time marker [75, p127].

Each EEG wave has been found to have associations with our specific emotions and behaviour. For instance, the Delta wave is easily observed when a person is in a deep sleep, and the power of the Delta wave measured in the frontal region of the brain has been found to be significantly higher when the subject was viewing the picture of a loved one compared with the picture of an unknown person [76]. The power of the EEG frequency band is the power of an EEG signal contributed by the frequency components lying within each typical EEG frequency band. The Theta wave is observed with low-level alertness in young adults and the Theta power recorded from the frontal midline of the scalp has been found to be positively correlated with the emotional state of pleasantness [2, p69, 77]. The Alpha wave is observed in any person who is sitting quietly with eyes closed, in a relaxed state. Any mental work will cause reduction of the amplitude or disappearance of the Alpha wave. The Alpha wave and the brain activity are inversely related, which means a reduction of the Alpha wave indicates an increase of brain activity. The difference of the Alpha powers in between the left and right frontal regions of the brain has been suggested as an indicator of people's emotional state as seen in the frontal EEG asymmetry model described in the following section [78]. The Beta wave is a label of an excited mental state. It is commonly observed when a person is involved in alertness or cognitive processes. Greater Beta powers in the frontal, central and parietal regions of the brain have been observed in response to negative stimuli [79]. The Gamma wave is observed when a person responds to sensory stimuli and the Gamma power has been found to be increased in response to unpleasant emotional stimulation [2, p70, 80, 81]. Therefore, in the current research, a viewer's EEG signals corresponding to particular patterns are analysed in their frequency band powers, and the results are analysed and interpreted in relation to emotional responses of every pattern.

2.4.3 *Frontal EEG Asymmetry model*

The frontal EEG asymmetry model is a theoretical model proposed by Davidson regarding the relationship between asymmetrical anterior activation of the brain and human emotion-related processes. The asymmetric cortical activity at the frontal region of the brain had been found to be associated with emotional processes in early studies. Most of these studies had observations on patients who had suffered damage on the right or the left anterior cortex. The studies found the patients who had left hemisphere damage or lesions were more likely to show depressive symptoms, and patients having the lesion closer to the frontal region of the brain had more severe depressive symptoms; whereas, the patients who had right hemisphere lesions were more likely to show manic symptoms [82, 83]. According to the early studies, Davidson hypothesised that "*activation in the left anterior region is associated with approach-related emotions; deficient activation in this region is associated with emotion-related phenomena that might be best described as reflecting approach-related deficits such as sadness and depression; and activation in the right anterior region is associated with withdrawal-related emotions such as fear and disgust and withdrawal-related psychopathology such as anxiety*". Davidson described that the approach and withdrawal are classified as two fundamental motivational systems that organise behaviour. The approach system involves behaviour that is prompted by a possible desirable outcome, whereas the withdrawal system involves behaviour that is caused by a possible aversive outcome [82].

Davidson and colleagues had examined the theoretical model by conducting experiments with adult and infant subjects, and their results had supported the theoretical model [84, 85, 86, 87, 88]. For instance, they used short film clips to induce adult subjects' positive emotions, such as happiness and amusement, and negative emotions, such as disgust; meanwhile the subjects' facial reactions and EEG activities were recorded. According to the facial expressions, the corresponding EEG activities with positive and negative emotions were extracted and separately analysed. Davidson and colleagues found that the Alpha power is lower in the left frontal region of the brain during the happy facial expression; and the Alpha power is lower in the right frontal region during the disgust facial expression than the happiness expression. The lower Alpha power indicates increased activity in the cortex. Therefore, the experimental results show that greater left frontal activation of the brain is associated with positive emotion (happiness); whereas the greater right frontal activation is associated with negative emotion (disgust). In an experiment with infant subjects, Davidson and colleagues observed infants' smiles when approaching their mother and a stranger and the subjects' EEG signals corresponding to these two types of smile were compared. The experimental results showed that the EEG asymmetry in the frontal region of the brain was significant, in which relatively more left frontal EEG activation was associated with the smile when the infants approached their mothers. Coan and Allen conducted a review on nearly 100 studies on the frontal EEG asymmetry and human emotion. They concluded that the frontal EEG asymmetry is a mediator of activation in emotional processes, for example, "*the fear response would not occur, or would occur differently, or would occur at a lower level of self-reported intensity, if there was no change in frontal EEG asymmetry in the direction of increased relative right activity* " [78].

The front EEG asymmetry model has been used in researching human emotional responses to different stimuli. Especially in marketing research, the model has been employed in analysing consumers' responses to TV advertisements [89, 90, 91, 92] and predicting costumers' preferences for different product designs [93]. The model has also been used in research of emotion and preference induced by music [94], and in studies of colour influence on people's performance and emotional responses [95, 96]. Researchers have claimed that the front EEG asymmetry model can be used as a measurement tool on people's emotions when responding to a stimulus. The model has not been previously used in any study of pattern and hence the current study is the first to apply the frontal EEG asymmetry model for measuring viewers' emotional response to the effect of pattern necessary for further developing pattern-changing psychotextiles. The EEG signals that correspond to pattern viewing and the asymmetry score of the EEG Alpha power in the frontal region of the brain are calculated to determine the asymmetric activation of the brain and reveal approach or withdrawal related emotions corresponding to different pattern attributes. Consequently, this research will extend the knowledge in the effects of pattern in neuroscience. It will establish the interface between neuroscience and materials, and also establish the development of active SMART textiles as psychotextiles in commercial end uses and in art and design.

2.4.4 *Event-related Potential (ERP)*

Event-related potential (ERP) represents the brain response to a specific event. This event could be a sensory stimulation through vision, auditory, olfactory, gustatory, somatic sensation and vestibular, an absence from a regularly presented stimulation, or a physical and mental task [2, p145-151]. The electrical activity of the brain changes as soon as the response is occurring. Some changes are large enough to be identified in the primary EEG signal, but some are rather small and concealed inside the unrelated spontaneous brain activities. In order to discriminate the electrical activity that is corresponding to a specific event from the noise that is generated by unrelated activities, a signal averaging approach was used to increase the amplitude of the event-related signal relative to noise, in which the specific event has to be repeatedly presented or conducted for a number of trials, then the time-locked EEG signals corresponding to the events are extracted from the continuous EEG record, aligned and the amplitudes on each time point in the signal are then averaged. Connecting the averaged amplitude on each time point obtains a wave form, which is the ERP [2, p151-156]. Given an example of an ERP experiment by Luck [97, p7-12] shown in Figure 2-4, it aims to measure the participant's brain response to a frequent display X and an infrequent display O. The experimental setup is shown in section A and the continuous EEG signal recorded at the Pz location of the brain is shown in section B. The time-locked EEG signals corresponding to 80 times of display X and 20 times of display O are extracted, aligned and averaged as shown in section C. The two averaged ERP waves shown in section C represent the changes of the electrical potential of the brain when responding to the display X and display O respectively.

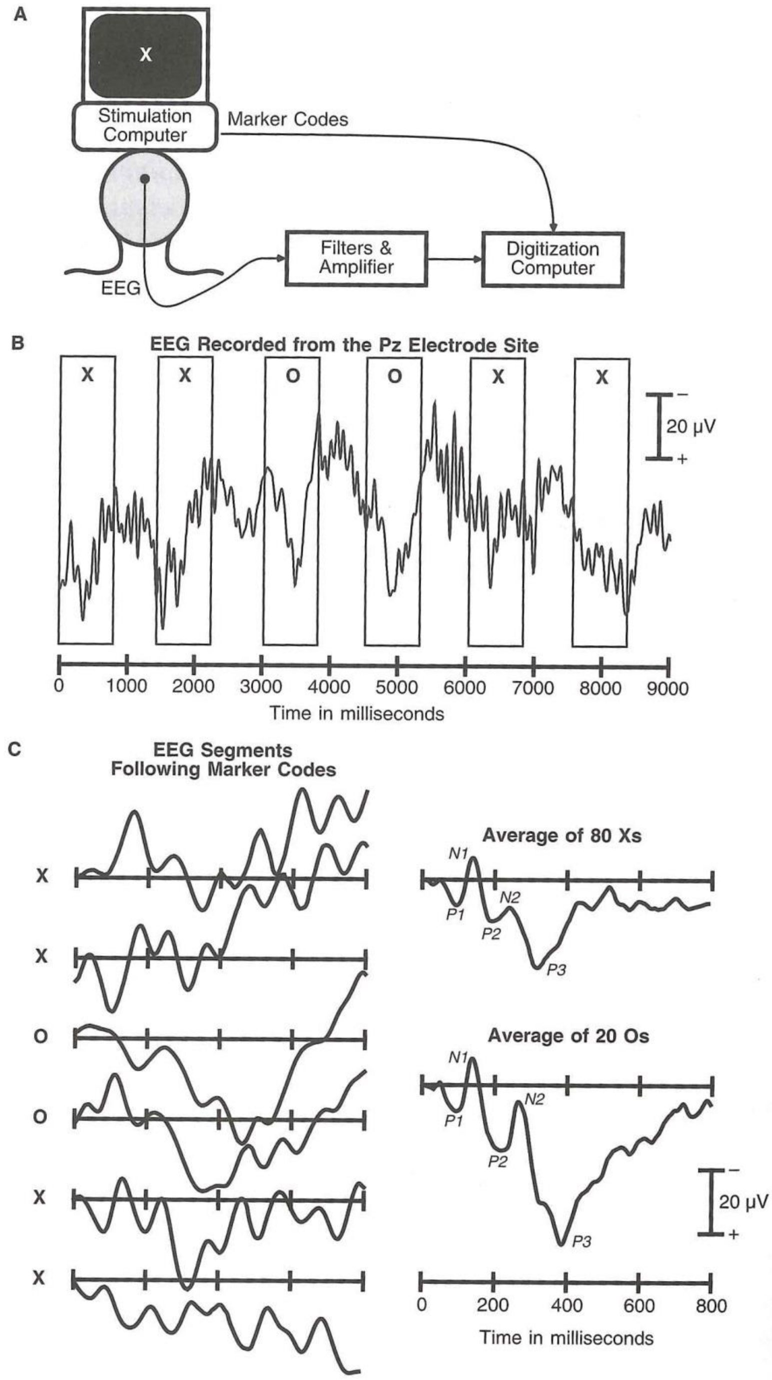


Figure 2-4 The experimental settings of a typical ERP experiment [97, p8].

The principle of the signal averaging approach is that the evoked brain response by the specific event is assumed to be the same at each trial and the unrelated brain activity randomly occurs from trial to trial; when a number of trials are averaged, the averaged brain response to the specific event remains the same but the unrelated brain activity decreases; if N is the number of the trial, the signal-to-noise ratio increases as a function of √ N (the square root of the number of trials). Therefore, the more trials are averaged together, the smaller the noise remains in the averaged ERP [97, p131-135].

ERP measurement has been widely used in studies of human brain activity associated with different human behaviours including emotion [2, p178-205, 98, 99]. Some components in the ERP wave are prominent to be identified. As seen in section C of Figure 2-4, there are 5 components in both ERP waves. They are P1, N1, P2, N2 and P3. Component P1 is the first prominent positive wave; component N1 is the first prominent negative wave; accordingly, components P2 and P3 are the second and third positive waves respectively, and N2 is the second negative wave. The occurrence, the amplitude and latency of the ERP components have been found to vary depending on the visual parameter of the stimulus and the testing subject's psychological state. For example, the latency of the component P1 has been found to be sensitive to stimulus contrast, and its amplitude is affected by the subject's arousal level, in which increased arousal leads to a larger P1 component [100]. The P1 component has also been found to be modulated by selective attention, in which the amplitude of the component is increased by an attended stimulus compared with an unattended stimulus [101, 102]. The amplitude of component N1, measured in the visual brain, has been found to be influenced by some visual parameters of the stimulus, such as the angularity, size and noise [2, p196-203]. The amplitude of the N1 component has also been found to be greater in response to the stimuli occurring in an attended location compared with the stimuli in an unattended location [103, 104, 105]. In relation to emotional experience, researchers have found that emotional stimuli containing either positive or negative valence effects trigger greater amplitude of the N1 component than those having a neutral valence effect [106, 107]. Researchers also found that the latency of the N1 component is influenced by the level of the processing effort, in which the latency increases when tasks require greater attention or effort [108, 109]. There are very few findings of components P2 and P3 relating to visual stimulation.

In this research, each viewer's visual brain response to a pattern stimulus is measured by using the ERP technique, so that the brain/pattern interaction can be established. By analysing the evoked ERP components, the visual effects of the pattern can be measured, from which the viewer's emotional response is interpreted. Therefore, in this research, we try to determine from the ERP model the effect of pattern change on a viewer's visual brain and its consequent trigger of different emotions.

2.5 Measurement of Heart Rate Changes

Change of cardiac activity has been found to occur in different emotional states, such as fear, anger and anxiety. Cardiac activity can be measured by the profile of the heart rate, particularly the changes of the speed of heartbeat defined at beats per minute (bpm) [2, p410]. Heart rate changes can be calculated by using an electrocardiogram (ECG), which is "*a recording of the electrical potentials generated by the heart"* [2, p436]. Researchers have found a pattern of heart rate change when responding to pleasant and unpleasant stimuli [110, 111, 112]. For instance, researchers referred to the testing subjects' self-rating score on the effective pictures to separate the corresponding heart rate changes into groups of pleasant and unpleasant stimuli. The mean of the heart rate changes was assessed for each group across the testing subjects. A triple phasic pattern of heart rate change was observed in response to both pleasant and unpleasant pictures, as shown in Figure 2-5. There is an initial heart rate deceleration, followed by acceleration and ending by a secondary deceleration. The initial heart rate deceleration is related to the stimulus intake and the orienting response. Orienting response is "*an organism's immediate response to a change in its environment by a novel or significant stimulus"*, and the heart rate deceleration that occurs during the orienting response leads in "*enhancing the input of the stimulus that an individual is attending"* [113, 114]. The unpleasant pictures evoke larger initial heart rate deceleration compared with the pleasant pictures. This result was profound in subjects who did not fear the contents of the picture. In the following heart rate acceleration, the pleasant pictures trigger a greater peak than the unpleasant pictures. As a result, a significantly greater heart rate deceleration is associated with the response to unpleasant stimuli, and relatively higher peak acceleration is associated with the pleasant stimuli. A constant pattern of the heart rate changes has been found in studies that used different stimuli, such as colour [115], film clips[116], sound[117] and music[118].

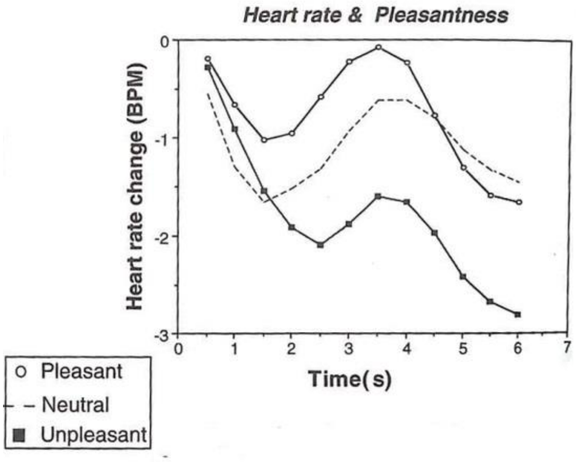


Figure 2-5 Heart rate changes as a function of picture valence [119, p256].

In the present research, viewer's heart rate changes corresponding to different pattern attributes are investigated. The results will be correlated further with brain measurement as an objective assessment of viewers' emotional responses and implemented in the design and development of psychotextiles.

2.6 Subjective Evaluation

2.6.1 *Self-Assessment Manikin (SAM) affective rating system*

Self-Assessment Manikin (SAM) is a rating system for assessing people's emotional response to a given stimulus. It is based on the Pleasure-Arousal–Dominance (PAD) Emotional-State Model, which is proposed by Mehrabian and Russell [5]. They claimed that three essential dimensions of human emotion: pleasure-displeasure, arousal-nonarousal, and dominance-submissiveness can adequately describe various human emotional states. Their theory is built on the three basic semantic differential factors of meaning found by Osgood, Suci and Tannenbaum [120], which are evaluation, activity and potency. Mehrabian and Russell adopted these three factors and proposed emotional dimensions corresponding to each of the three factors. Pleasure-displeasure is defined as the positive versus negative affective state corresponding to cognitive judgements of evaluation, with higher evaluation of stimuli associated with greater pleasure. Arousal-nonarousal is defined in terms of the level of alertness and physical activity in which a positive emotional dimension is attributed to higher stimulus. Dominance-submissiveness represents a feeling of control and influence over one's surroundings versus an inability to influence a situation or a feeling of lack of control

[121]. The pleasure-arousal-dominance (PAD) emotional state model has been used to assess a subject's emotional response in different studies, for example, in the perdition of product preference [122], in investigation of the desirability of a first name [123], in the emotional effect of colour [124] and in a study of predicting a person's physical attractiveness [125].

However, in practice using the PAD model is time consuming and requires large effort and expertise for analysis, and it relies on verbal semantic differential rating scales, which causes difficulties when being used in non-English speaking cultures. To improve these shortcomings, Lang and his team depicted the PAD model with a non-verbal, graphic representation rating system, named the Self-Assessment Manikin affective rating system (SAM) [3, 4]. This system can be used directly to assess the three basic emotional dimensions, but avoiding the semantic differential scales and linguistic interferences. Figure 2-6 shows a typical paper-and-pen version of the SAM system. It consists of three major affective scales; Valence, Arousal and Dominance. Each of them has five various nonverbal graphic characters arranged along with a nine-point rating scale. In the Valence scale, SAM ranges from a frowning, unhappy figure to a smiling, happy figure; in the Arousal scale, SAM ranges from a relaxed, sleepy figure to an excited, wide-eye opened figure; in the Dominance scale, SAM ranges from a very small figure representing a feeling of being controlled or submissive to a very large figure representing maximum control in a situation or a powerful feeling. During testing a subject is asked to place an 'x' over any of the five figures in each scale, or between any two figures, to report his/her response while exposed to the testing stimulus. There are nine point ratings in each scale. In the figure, score 9 represents the highest rating on each scale, such as highest Pleasure, highest Arousal, and highest Dominance; while score 1 represents the lowest rating on each scale; the lowest Pleasure, lowest Arousal, and lowest Dominance. Statistical techniques are applied in the analysis of the collected rating scores.

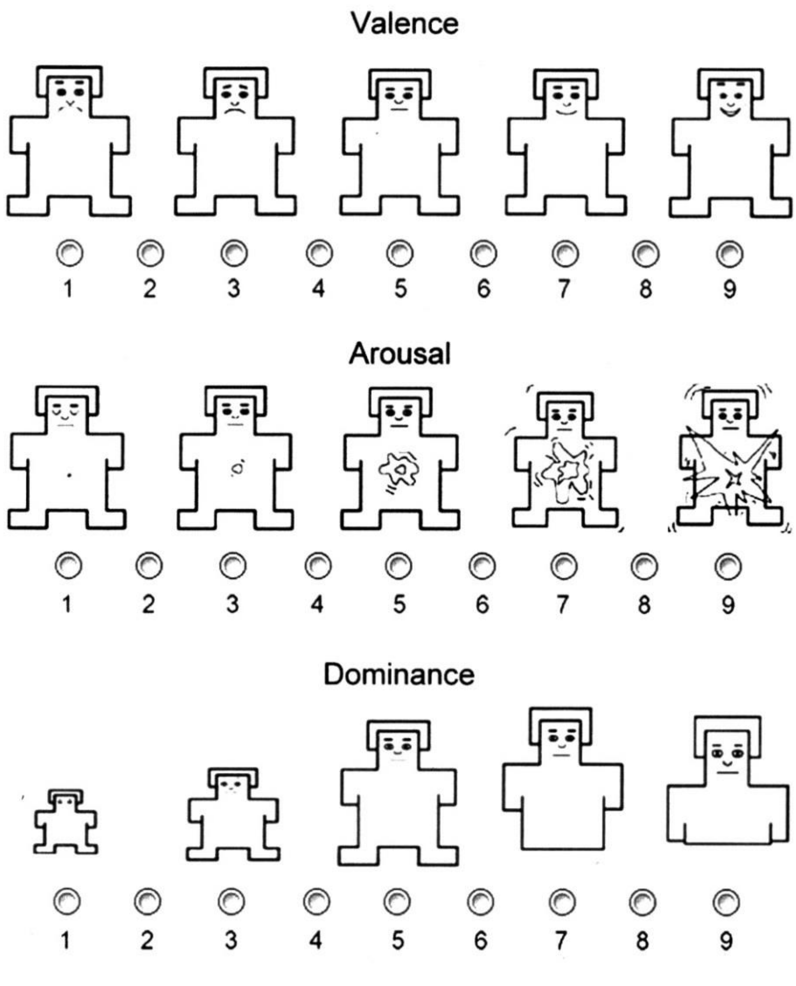
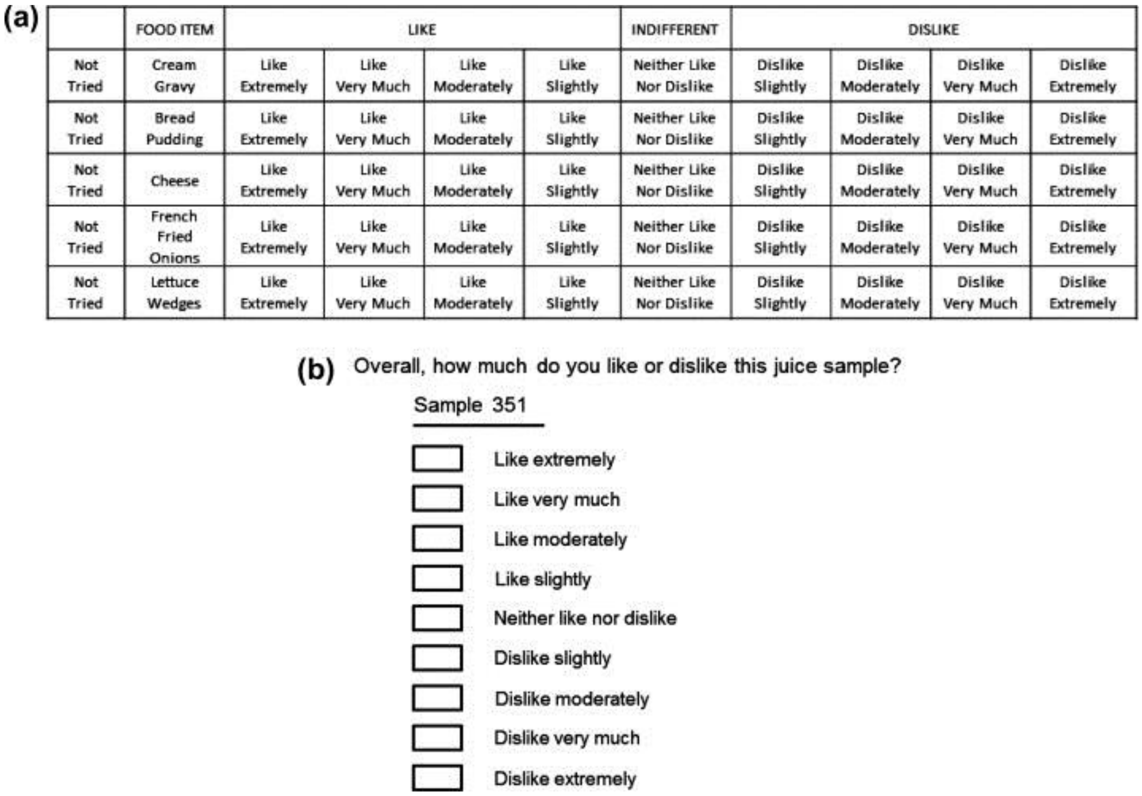


Figure 2-6 A typical paper-and-pen version of the Self-Assessment Manikin (SAM) [126].

The correlation between the SAM system and the PAD model had been studied by Bradley and Lang [127]. Their results showed that pleasure and arousal scales almost agreed in all comparisons between the semantic differential factor scores from the PAD model and the rating results from the SAM system; but disagreement was found in the dominance dimension. Bradley and Lang explained that judgement of the dominance dimension indicates the interactive relationship existing between the participant and the stimulus, and it will require specifying which member of the relationship is being judged; the different result between the two systems suggests that the PAD model may cause confusion in regard to which member of the interaction is being rated and therefore leads to testing participants rate on the stimulus' dominance instead of his/her feeling of dominance; whilst the figure of the SAM system clearly indicates that they are presenting the testing participant's feeling of dominance, therefore, the SAM system has an advantage in this case. The SAM system has been used in measuring people's emotional response to various situations, including reactions to pictures, images, sound, advertisements, and more. In particular, it has been used to develop the International Affective Picture System (IAPS) database [128] the purpose of which is to provide standardised picture stimuli for the psychological research of emotion. The SAM system is used in this research to assess viewers' emotional responses to pattern along with the measurements of the brain activity and heart rate change.

2.6.2 *The 9-point hedonic scale*

The 9-point hedonic scale was originally invented for evaluating acceptability and preference for the foods supplied in the US Armed Forces [129, 130]. Two examples of the 9-point hedonic scales are shown in Figure 2-7. The scale consists of 9 categories in a balanced bipolar structure. The neutral category (Neither like nor dislike) is in the centre of the scale and four positive categories (Like extremely, Like very much, Like moderately, Like slightly) and four negative categories (Dislike slightly, Dislike moderately, Dislike very much to Dislike extremely) are on each side. The scale allows testing subjects to describe their responses by choosing one of the categories accordingly. In the subsequent analysis, the 9 categories are converted to numerical values, for example, the category "Like extremely" as 9, "Dislike extremely" as 1, and the values of categories in between are 8, 7, 6, 5, 4, 3, 2, so that experimenters are able to quantify the testing subjects' response in terms of the degree of liking/disliking, and therefore to discriminate people's preference to the measuring products.



(a)

	FOOD ITEM	LIKE				INDIFFERENT	DISLIKE			
Not Tried	Cream Gravy	Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
Not Tried	Bread Pudding	Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
Not Tried	Cheese	Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
Not Tried	French Fried Onions	Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely
Not Tried	Lettuce Wedges	Like Extremely	Like Very Much	Like Moderately	Like Slightly	Neither Like Nor Dislike	Dislike Slightly	Dislike Moderately	Dislike Very Much	Dislike Extremely

(b) Overall, how much do you like or dislike this juice sample?

Sample 351

- Like extremely
- Like very much
- Like moderately
- Like slightly
- Neither like nor dislike
- Dislike slightly
- Dislike moderately
- Dislike very much
- Dislike extremely

Figure 2-7 Two samples of the 9-point hedonic scale: (a) Questionnaire designed for assessing soldier's preference in the field [129], and (b) a sample used in common consumer tests in a laboratory setting.

There have been various presentation formats of the 9-point hedonic scale since its first development. The scale could be presented vertically and horizontally. In the case of a horizontal scale, the category of "Like extremely" could be placed on the left or on the right. The scale could contain verbal categories only such as the original one or contain 9 boxes with categories "Like extremely" and "Dislike extremely" on each end [131]. Alternative scales could consist of value numbers only, in which case the 9 verbal categories are replaced by numbers such as 1-9. The scale could also have both value numbers and verbal categories, such as 9 value numbers along the category boxes and the "Like extremely" and "Dislike extremely" labels at each end with or without the "Neither like nor dislike" label in the middle of the scale [132, 133, 134]. Concerns for these variations of the scale are whether they have an effect on the testing subjects' response and the measuring result. Researchers found no difference in the measuring results by using the vertically and horizontally presenting scales or the scales with the category "Like extremely" label located on the left or on the right [130]. Other investigations focused on the comparison between the "verbal categories only" scale and the "value number only" scale. Their results show that the data obtained from these two scales are not equivalent. It is caused by people's different cognitive strategies that are used on the scales. People who rated on "verbal categories only" scale use mostly absolute cognitive strategy, whilst people who rated on "value number only" scale use relative cognitive strategy. Although the mean values of the rating scores on these two scales are different, it doesn't affect the hedonic ranking orders of the measuring objects. Researchers also found that the mean scores derived from the "verbal category only" scale and the scale consisting of verbal category and value number are closer and the way people use these two scales are similar compared with the "value number only" scale. No significant impact of the presentation format of the 9-point hedonic scale has been reported on the hedonic measuring result, however researchers suggested that the scale presentation is best to be consistent across the compared studies, data obtained from the "verbal categories only" scale and "value number only" scale are not interchangeable, therefore direct comparison of these data is inappropriate [135, 136, 137, 138].

The 9-point hedonic scale is simple and easy for participants to use and requires less effort in data analysis, therefore it has been widely used in marketing research [139, p143] and sensory science [140, p275] for measuring people's hedonic response. This research uses the 9-point hedonic scale to measure viewers' preference for different pattern attributes.

2.7 Research Aim and Objectives

This research aims to investigate whether we can develop textiles that can actively influence our psychological state by their SMART functions. It focuses on the psychological effectiveness of the pattern-changing function of SMART fabrics. Firstly, this research explored the emotional influences evoked by different attributes of a pattern. Two paired patterns were studied: repeating and non-repeating patterns, weak and intense patterns. Repeating pattern contains regularly repeating elements and has symmetrical and continuous features, whilst non-repeating pattern contains irregularly repeating elements and has asymmetrical and discontinuous features. Weak pattern is faint, light and simple compared with intense pattern that is high in contrast, bold and complex. In order to find out how such variations in a pattern could impact on viewers' responses, this research carefully selected representative samples of each type of pattern, designed and conducted controlled experiments, in which participants were exposed to these samples whilst their EEG and ECG signals were recorded. The corresponding

EEG and ECG signals of each sample were then analysed. The five frequency band powers of the EEG signals were calculated and interpreted in relation to emotion. The frontal EEG asymmetry model was applied for specifically analysing a participant's approach-withdraw emotional experience to the pattern. The subjective evaluation of emotional response and preference for each sample were also carried out by using the SAM system and the 9-point hedonic scale. Participants' responses to the two paired patterns were then compared and the mean of their difference was calculated by using statistical hypothesis testing and confidence interval estimation. Significant differences observed in the experiments were then analysed and interpreted in relation to viewers' emotional responses, so that the difference of the effects evoked by the two paired patterns were established. Secondly, this research went on to actively design fabrics that can generate specific emotions by switching its patterns. These patterns were chosen from the previous study. A new SMART colour-changing electrochromic composite yarn was developed and it was used in both knitting and weaving processes to produce fabrics that can change patterns from one to another. A collection of fabrics was carefully produced, for which pattern-changing effects require being repeating to non-repeating and being weak to intense. Finally, further experiments were conducted to verify the pattern-changing effects of the fabrics on viewers' psychological responses, using the same measurements as described in the previous section. Comparison of brain wave responses, heart rate changes and subjective evaluations between the two patterned appearances of each fabric and the interpretation of the differences in relation to emotion reveal the emotional effect caused by the SMART pattern-changing function of the fabric, so that we can establish the notion of actively designing emotional influences using SMART textiles and hence name them as psychotextiles. Based on literature, our visual response is affected by some pattern shapes, corners, size and noise. This research also investigated the visual effect triggered by the pattern change of the SMART fabrics. People's visual response to the pattern was measured in their visual brain response by the event-related potential (ERP) method. The amplitude and latency of the ERP component evoked by the viewing of the two patterned appearances of each fabric were analysed and compared, so that the differences in people's visual responses to the pattern change could be revealed.

CHAPTER 3 EXPLORING THE EFFECT OF DIFFERENT PATTERNS ON HUMAN EMOTIONS

The current chapter aims to explore the emotional influence evoked by different pattern characteristics. Repeat, symmetry and continuity are often seen in daily life, such as in architecture, interior design, photographs and art. In order to find out how such characteristics in a pattern could effect viewers' emotional responses, this research studied two pattern types: repeating vs. non-repeating. Repeating pattern contains regularly repeating elements and has symmetrical and continuous features, whilst non-repeating pattern contains irregularly repeating elements and has asymmetrical and discontinuous features. This research also explored the emotional influence evoked by the intensity and complexity of pattern. Another pair of pattern characteristics: weak vs. intense were studied. Weak pattern is faint, light and simple compared with intense pattern that is high in contrast, bold and complex. This research carefully selected the representative samples of each type of pattern, designed and conducted controlled experiments. The responses of 20 participants were measured by their physiological reactions as well as their subjective evaluation as previously described. Participants' physiological reactions were measured directly by their brain waves and cardiac activity. The brain wave EEG signals were analysed on the five frequency band oscillations (Delta, Theta, Alpha, Beta, and Gamma), whilst the cardiac responses by heart rate changes. The Frontal EEG Asymmetry model was applied for analysing participants' approach-withdraw emotional experiences when viewing a pattern. In the subjective evaluation, every participant's emotion was assessed by using the Self-Assessment Manikin (SAM) and their pattern preferences by using the 9-point hedonic scale. The significant differences of the responses between two paired patterns were determined by the statistical hypothesis testing technique. When differences were established, the confidence intervals of the mean of these differences were computed and analysed. The combination of physiological measurements and subjective evaluation can reveal specific pattern characteristics that can affect human emotions. If these effects are established, these pattern characteristics can be transferred to real products such as in the case of SMART textiles in which switching of one pattern to another will be possible.

3.1 Designing Representative Samples of Defined Types of Pattern

Based on literature, downward pointing triangles were found to be associated with unpleasant emotional response; stripe and checker board patterns installed in a living space have a significant effect on users' behaviour; face symmetry has a positive influence on attractiveness; over stimulating environments with complex or incongruous visual patterns have been found to increase viewers' emotional feelings. Despite the lack of systematic studies, there is a clear indication that features of pattern have influence on people's emotions and feelings. How characteristics of repeat, symmetry, continuity, intensity and complexity of pattern could effect on our emotion? This research therefore proposed two paired pattern types: repeating/non-repeating and weak/intense that covers these pattern attributes, and investigated the different emotional effect of each pair. As shown in Figure 3-1, a repeating pattern is a pattern that contains regularly repeating elements and has symmetrical and continuous features, whilst a non-repeating pattern is a pattern that contains irregularly repeating elements and has asymmetrical and discontinuous features. As shown in Figure 3-2, weak pattern is faint, light and simple compared with intense pattern that is high in contrast, bold and complex.

Repeating Patterns		**Non-repeating Patterns**
• Regularly repeating elements	↔	• Irregularly repeating elements
• Symmetrical	↔	• Asymmetrical
• Continuous	↔	• Discontinuous

Figure 3-1 Defining the attributes of repeating and non-repeating patterns.

Weak Patterns		**Intense Patterns**
• Faint	↔	• High in contrast
• Light	↔	• Bold
• Simple	↔	• Complex

Figure 3-2 Defining the attributes of weak and intense patterns.

The representative samples of each defined type of pattern were carefully deigned. Consideration has been also put in for further implementation of the fabric production with the patterns. All pattern samples used in the current study were black and white for avoiding the influence of colour, and their details are described as follows.

3.1.1 *Repeating and non-repeating patterns*

Eight representative samples of repeating patterns were carefully selected as shown in Figure 3-3. They are all symmetrical patterns with continuously repeating shapes and forms. Sample A1 contains vertical lines that are composed of small diamond shapes. The arrangement of the lines is in a regularly repeating order. Sample C2 consists of three sections of identical zigzag lines that are repeating in a same order. Sample E1 is composed of many small squares that are placed in a systematic and repeating arrangement. Sample F1 contains larger square shapes and each of them has a smaller square within. The squares are repeating in a well-regulated order. Both sample G1 and G2 have diamond shapes in two different sizes. The diamond shapes are replicated in a constant order. In sample H2, there is a symmetrical motif placed on the top of regularly repeating diamond shapes. Finally, sample I1 contains small dots that form repeating square shapes.

Eight representative samples of non-repeating patterns are shown in Figure 3-4. They are all asymmetric patterns with discontinuous and non-repeating elements. Both samples B1 and B2 contain undefined forms, with the difference that sample B1 is filled with small black squares, whilst sample B2 is filled with black stripes. Sample C1 contains many downward pointing V shapes, which are in different thicknesses and randomly placed in the pattern. Sample E2 consists of many square and rectangular shapes, which are arranged in an irregular order and some of which are filled with black colour. Sample F2 contains square and rectangular shapes in various sizes and some of them are filled with black colour, which are non-repeating and irregular. In sample H1, there is an uncompleted motif covered by randomly placed small square shapes, some of which are filled with black colour. Sample J1 is composed of vertical stripes, which have different thicknesses and are arranged in an irregular order. Sample J2 has the same stripes as sample J1. The difference is that sample J2 also contains triangle shapes that are in different sizes and arranged in a random order.

Repeating pattern

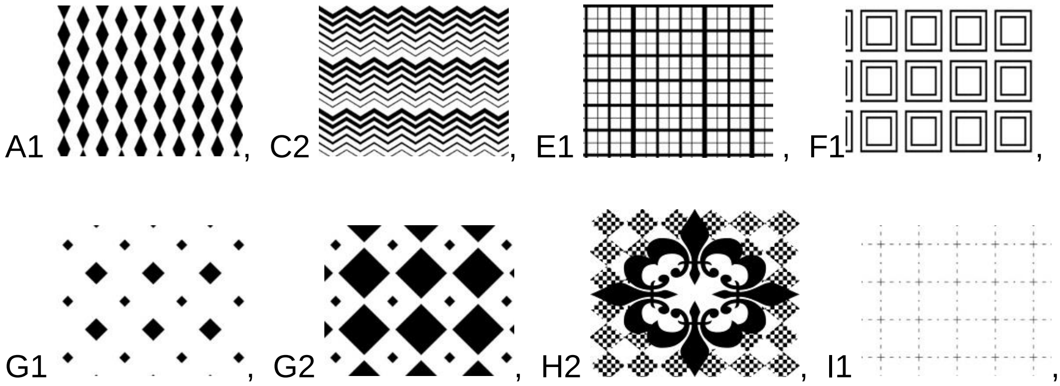


Figure 3-3 Eight representative samples of repeating pattern.

Non-repeating pattern

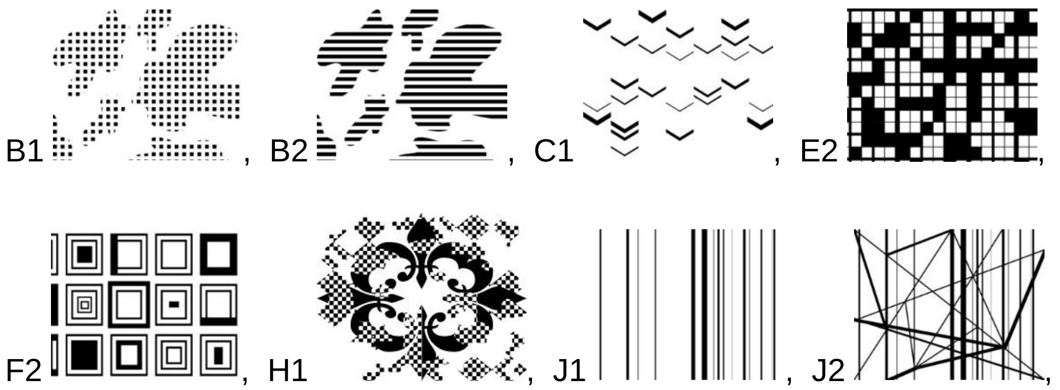


Figure 3-4 Eight representative samples of non-repeating pattern.

3.1.2 *Weak and intense patterns*

Eight representative samples of weak pattern are shown in Figure 3-5, and another eight representative samples of intense pattern are shown in Figure 3-6. Named alphabetically, eight pairs of samples (B1-B2, C1-C2, E1-E2, F1-F2, G1-G2, H1-H2, I1-I2 and J1-J2) were grouped and compared. Samples B1 and B2 are both non-repeating patterns with almost identical elements. The only difference is that sample B1 contains small square shapes in black colour, whilst sample B2 has thick stripes in black colour. Therefore, sample B2 is higher in contrast and bolder than sample B1. Sample C1 contains randomly arranged downward pointing V shapes, whilst sample C2 has regularly and continuously repeating zigzag lines. Therefore, sample C1 is loose and light, whilst sample C2 is intense and bold. Sample E1 is a repeating pattern with square shapes, whilst sample E2 is a non-repeating pattern with random square and rectangular shapes, some of which are filled with intense black colour. As a result, sample E1 is easier to define and simpler than sample E2. Sample F1 contains regularly repeating square shapes, whilst sample F2 has some square shapes as sample F1 but they are non-repeating and some are filled with blocks of black colour or other small squares within. Therefore, sample F2 is more complex than sample F1. Both samples G1 and G2 are repeating patterns with diamond shapes. The difference is that the diamond shapes of sample G1 are smaller than the ones of sample G2, so that sample G1 is loose and light, whilst sample G2 is high in contrast and bold. Samples H1 and H2 contain similar motif, however the one in sample H1 is uncompleted and covered with random square shapes, whilst the one in sample H2 is completed with regularly repeating square shapes in the background. Therefore, sample H1 is loose and light whilst sample H2 is intense and bold. Samples I1 and I2 are repeating patterns. However, sample I2 has repeating motifs in intense black colour, whilst sample I1 only has tiny dots that consists of square shapes. Therefore, sample I2 is much more bold and complex than sample I1. Sample J2 has the same vertical lines as sample J1 but also contains different triangle shapes. As a result, sample J2 is more complex than sample J1. In summary, weak pattern is faint, light and simple, whilst intense pattern is high in contrast, bold and complex.

<u>Weak Pattern</u>

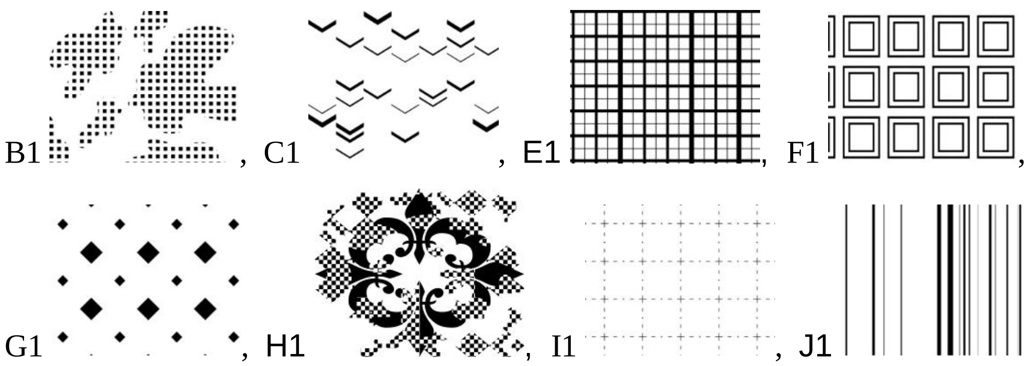


Figure 3-5 Eight representative samples of weak pattern.

Intense Pattern

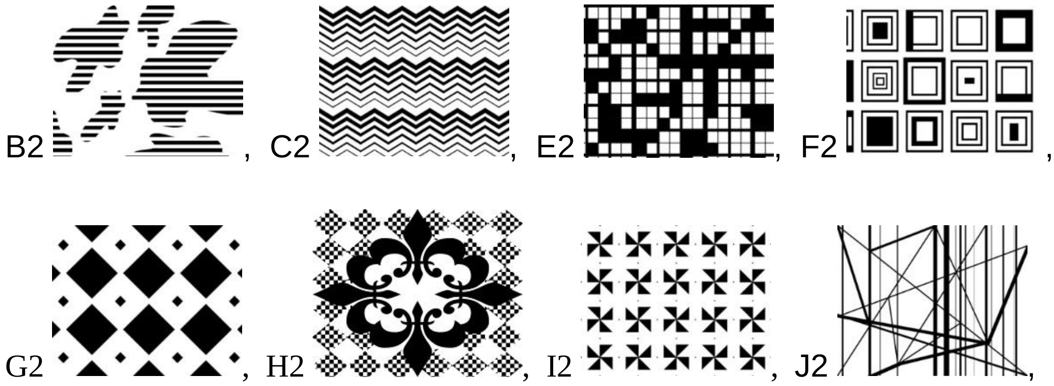


Figure 3-6 Eight representative samples of intense pattern.

The factor of repeating and non-repeating is another factor right the way through the weak and intense patterns. Consequently, the difference of people’s response to these variables was investigated. In order to separate potential causes, each group of repeating and non-repeating patterns contains half samples of weak pattern and half samples of intense pattern; in weak and intense patterns, each pattern is designed and arranged so that it contains half of repeating patterns and half of non-repeating patterns.

3.2 Experiment Design

3.2.1 *Participants*

20 volunteers participated in the current experiment. They were 11 males and 9 females. Their ages were between 23 to 54 years old (mean at 31.60 years old and standard deviation at 9.01 years old). They were all healthy and none had a history of epileptic seizures, a head or brain operation, claustrophobia or any known mental problems. They were all right-handed and had normal vision or corrected-to-normal vision by wearing spectacles. Before starting any experiment, participants were given the general outline of the experiment without any details of the experimental target. Appropriate written consent was obtained from them, and ethical forms completed and approved by the School of Textiles and Design of the Heriot-Watt University. Participants took part in the experiment as individuals and not collectively.

3.2.2 *Experimental stimuli*

20 graphical colourless patterns were used for the current experiment as shown in Figure 3-7. They include the 17 representative samples as shown in the previous section, additionally with sample A2, D1 and D2. Despite being a repeating pattern, sample A2 was discarded in the experiment analysis. It is because that it contains 3D visual effect that is very different from other pattern samples. Patterns D1 and D2 were also discarded in the analysis but were reserved for the implementation experiments, in which pattern-changing fabrics were made. During the experiment, each pattern was presented at the centre of a 19-inch monitor screen in a grey colour background. The displaying size of every pattern was 305mm in width and 245mm in height. All patterns were presented with the same brightness setting. The participant sat in front of the monitor at 1400mm distance during the experiment, so that the visual angle of the pattern stimuli was 12.4 degrees in the horizontal and 10.0 degrees in the vertical dimensions, which is calculated by the visual angle formula shown in Equation 1.

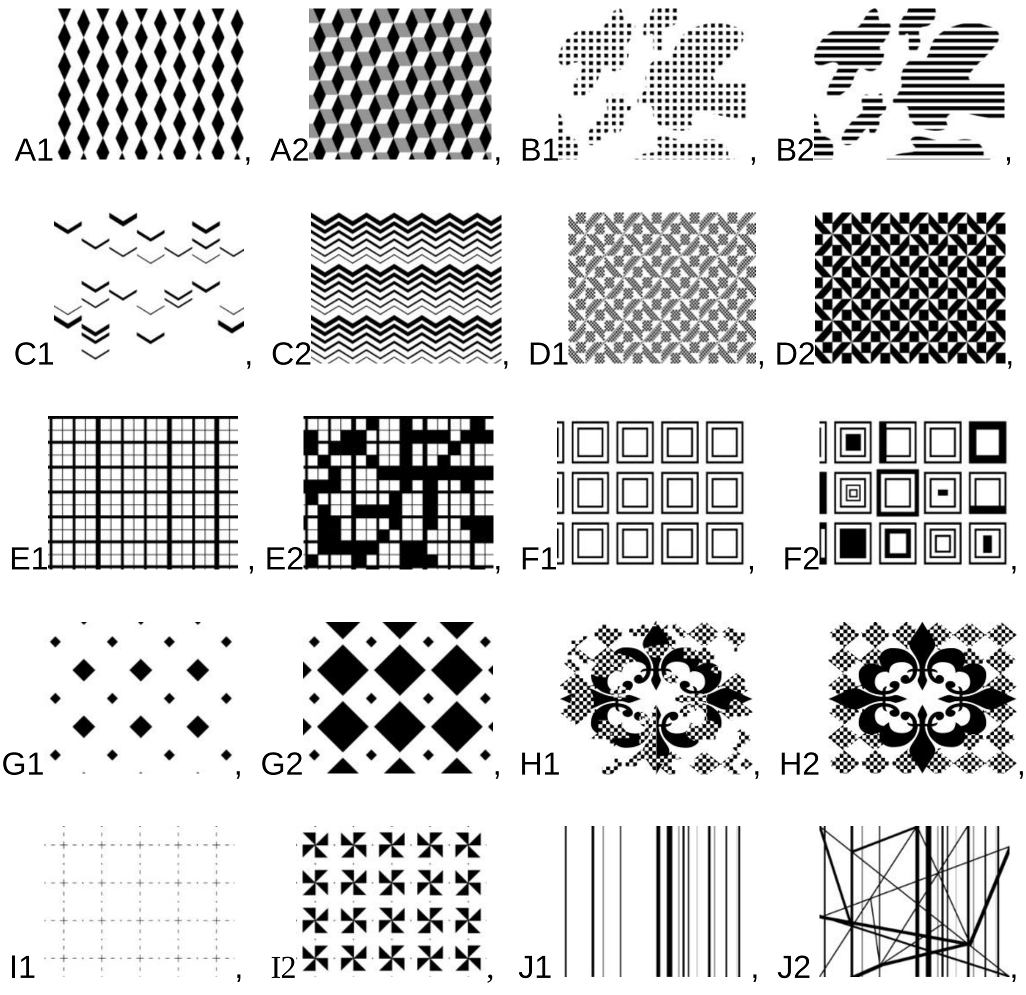


Figure 3-7 20 graphic patterns used in the experiment.

$$V = 2 \arctan(S/2D)$$

Equation 1 The visual angle formula [141].

3.2.3 *Experimental slides*

There are many different methods for this type of experiment in the literature, but standard practice is yet to be developed. The design of the current experimental slides is referred to the methods used in the literature. A personal desktop computer was used as the main relaying tool for the patterns. Slides were devised to provide instructions and the pattern stimuli. The order and duration of the slides were programmed by self-written scripts in the “Presentation” software. The coding of these scripts is reported in Appendices A.1 and A.2.

Every experiment consists of two parts, part 1 deals with the interaction between pattern and the brain and cardiac activities, and part 2 with the self-evaluation of each pattern. Figure 3-8 shows a diagram of the slides used in the first part of the experiment, in which each participant’s brain waves and cardiac responses to every pattern were recorded. A preparation slide was firstly presented for 8 seconds; then, a cycle was shown with instructions for eye movement including “eyes close”, “eyes open”, and “blink eyes” commands, aiming at reducing eye strain during the experiment, followed by a grey screen for between 2.5 seconds to 3.5 seconds, which was set at the baseline period before presenting the actual pattern stimulus for 11 seconds. The random length of baseline prevents the participant from anticipating exactly when the pattern stimulus will occur. This cycle was repeated 5 times. A “20 second break” instruction followed on the screen, the cycle then reappeared and this sequence was repeated until all patterns were presented. Patterns were shuffled randomly at the beginning of the presentation, and each of them was only presented once.

The diagram in Figure 3-9 shows the order and duration of slides used in the second part of the experiment. Each participant was asked to give his/her subjective rating on the SAM scales and the 9-point hedonic scale when viewing the patterns. The slides start with a preparation screen for 8 seconds, and then a cycle is shown with an instruction slide, followed by a pattern stimulus for 30 seconds. The cycle is repeated 20 times until all patterns are presented. Pattern stimuli were shuffled randomly before presentation and each of them was only presented once. A “thank you” slide was shown at the end of the session.

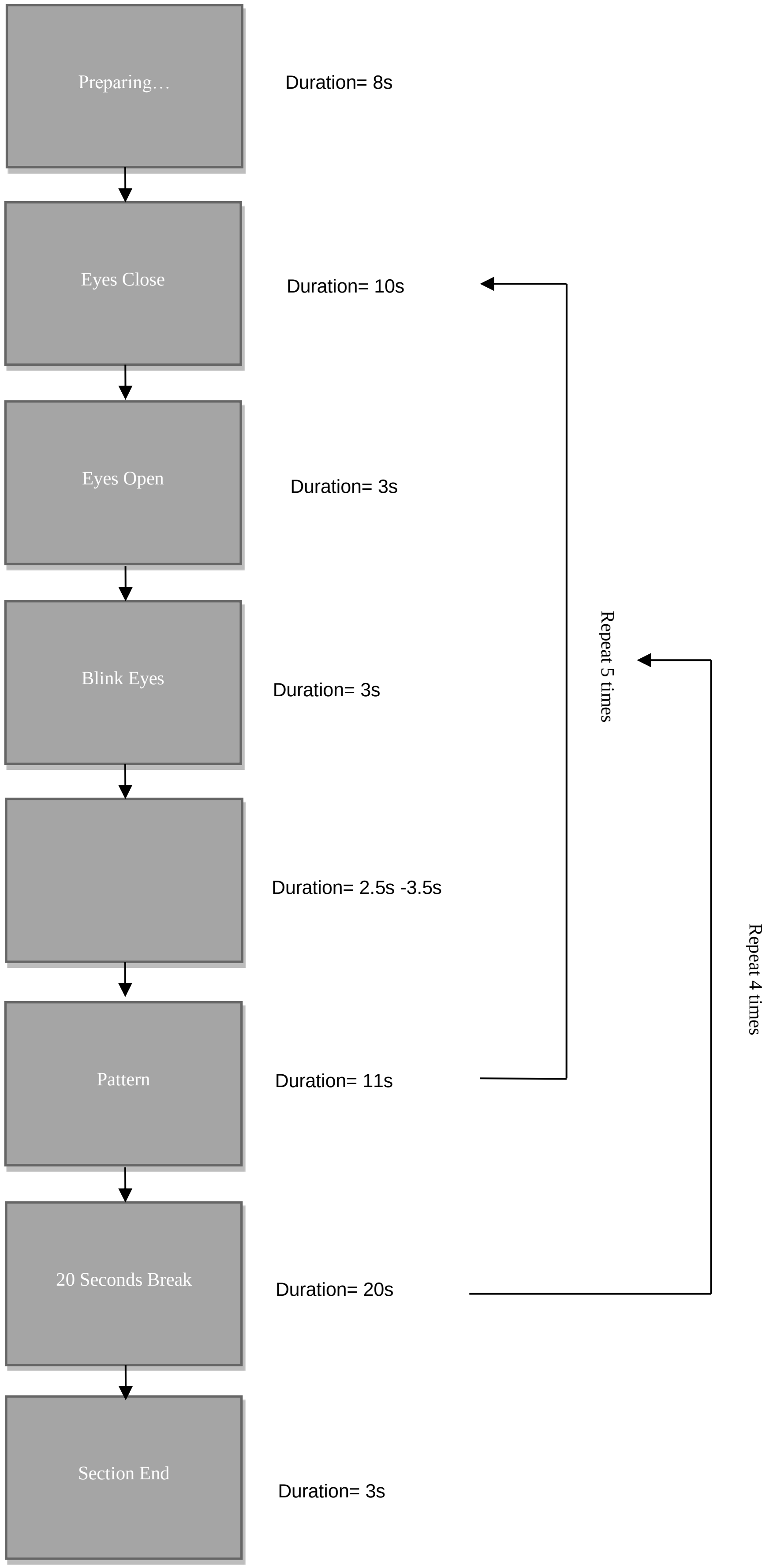


Figure 3-8 A diagram of the slides with the timing used in the first part of the experiment.

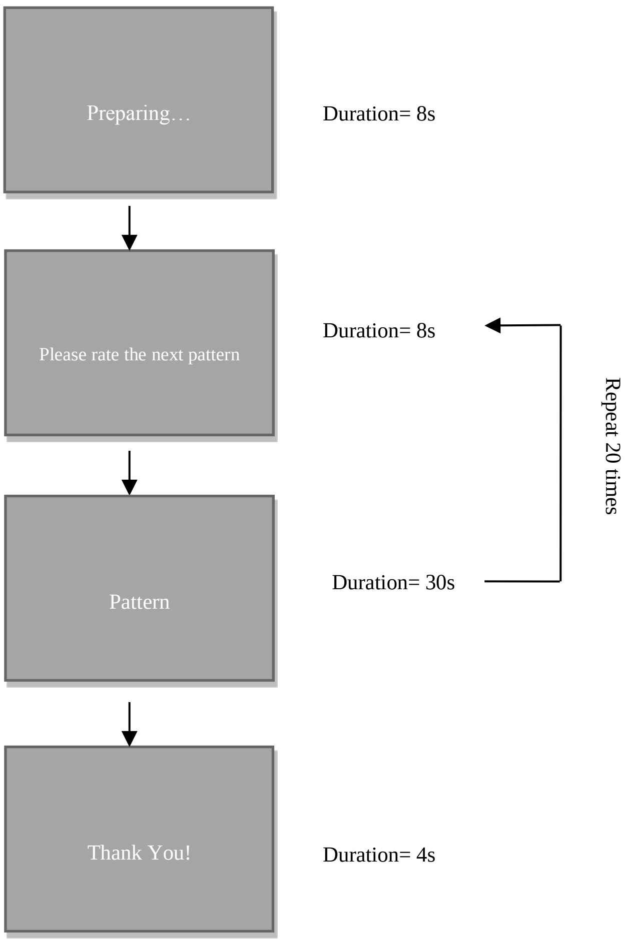
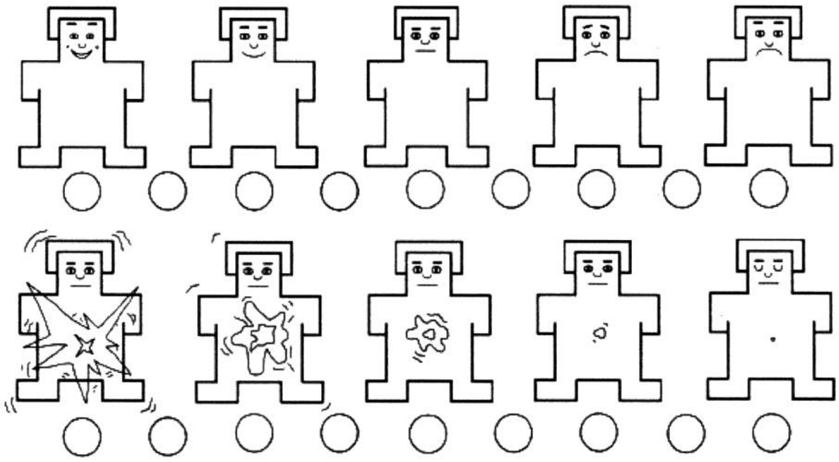


Figure 3-9 A diagram of the slides with the timing used in the second part of the experiment.

3.2.4 *Self-reported Rating Scales*

Self-reported Rating Scales were designed for participants to also evaluate their subjective emotional response and preference to the pattern stimuli, in addition to their brain waves and cardiac objective responses. As shown in Figure 3-10, there are three rating scales which include SAM and a 9-point hedonic scale. Two sets of 5 sketch figures along with a row of circles were the Valence and Arousal scales of SAM, and they were used by the participant to rate his/her emotions while viewing the patterns. The Likert (Like/Dislike) scale is a variation of the 9-point hedonic scale. It was used to score participants' preference for the patterns. The three scales were put together and named Self-reported Rating Scales in the current experiment. The participant was asked to mark all three scales for each pattern by placing an "X" over the circle.



Like O O O O O O O O O **Dislike**

Figure 3-10 The Self-reported Rating Scales in the experiment.

The Valence scale is presented in the first set of 5 sketch figures along with a row of circles. The figures range from smile to frown. When the participant felt completely happy, pleased, satisfied, or contented while viewing the pattern, he/she could indicate this by placing an “X” over the sketch figure at the left on its accompanying circle. When the participant felt completely unhappy, annoyed, unsatisfied or bored, he/she could indicate this feeling by placing an “X” on the sketch figure at the right side of the scale. The neutral, neither pleasant nor unpleasant state is represented at the middle of the scale. The scale also allowed intermediate feeling or even closely between two states, i.e., between two sketches, allowing finer graded ratings. The Arousal scale is presented in the second set of 5 sketch figures along with a row of circles. The Arousal scale is also interpreted in the same way as in the case of Valence with the only difference that it tests for excitement, wide-waking and arousal.

In the Likert scale, there are 9 rating circles along the scale without any value number or verbal label, except labels saying “Like” on the left end of the scale and “Dislike” at the right end of the scale. If the participant has a completely positive preference toward a pattern, an “X” is placed over the circle at the left of the scale; contrarily, for a dislike pattern an “X” over the circle at the right of the scale. The same provisions apply for intermediate ranking as in the case of Valence and Arousal scales.

3.2.5 *Experimental procedure*

3.2.5.1 Experimental preparation

The experiment was set in a well prepared and set-up laboratory in a sound-attenuated room. After arrival at the laboratory, the participant was given a brief introduction to the experiment and read the information before signing the consent form. Then, the preparation for the experiment was started. An ECI Electro-Cap shown in Figure 3-11 was applied on the participant prior to EEG recording. As seen in Figure 3-12, an ear electrode was attached on the participant's left earlobe. A pair of disc electrodes was used for recording the electrooculography (EOG), which is "*a measurement of electrical activity produced when the eyes move"*[2, p16]. One of the disk electrodes was attached 1cm above and lateral to the corner of the left eye; the other one was attached on the left mastoid, which was located just behind the outside ear in the lower part of the skull. A pair of ECG electrodes filled with conductive gel was placed above the participant's wrist, on the inside of their arms. The EEG cap and all electrodes were then plugged into the EEG system. The connection of all detected bio-signals was initially examined to ensure that all electrode impedances were less than 20 kΩ before starting the experiment.

Figure 3-11 ECI Electro-Cap and auxiliary tools for EEG signal acquisition.

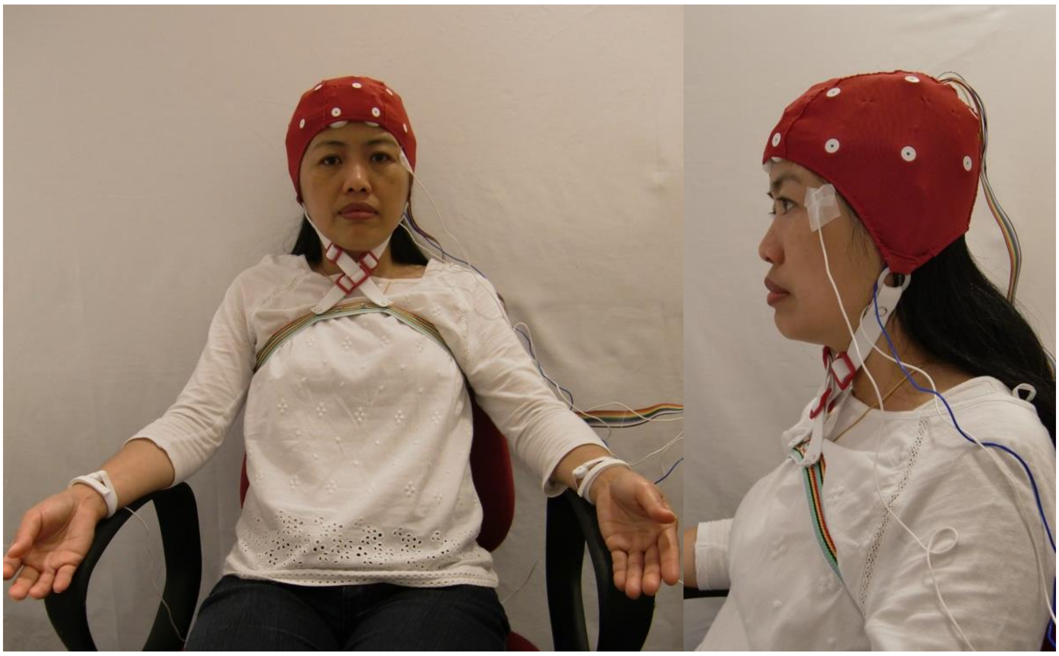


Figure 3-12 A participant wearing the EEG cap, ECG and EOG electrodes in the experiment.

3.2.5.2 Experimental part 1

During the first part of the experiment, the participant is seated in a reclining chair facing the presentation screen at 140 cm distance. Both the participant's hands were relaxed on the handles of the chair and the eye level was adjusted so that is at the centre of the screen. The participant was told that a series of instruction slides would be displayed on the screen and that some slides contained instructions such as eyes close, eyes open and blink eyes, and that some of the slides contained patterns. He/she was asked to be comfortable and relaxed and to look at the centre of the screen, to keep his/her body relaxed and to follow the screen instructions; the eyes open instruction was verbally given by the operator who was sitting behind the participant. The participant was also asked to view the pattern for the entire time and to avoid eye blinking, deep breathing or any other body movement. A couple of exercise trials were given to the participant prior the experiment, until he/she understood the instructions and felt comfortable. Figure 3-13 shows an image shown during a typical experiment.

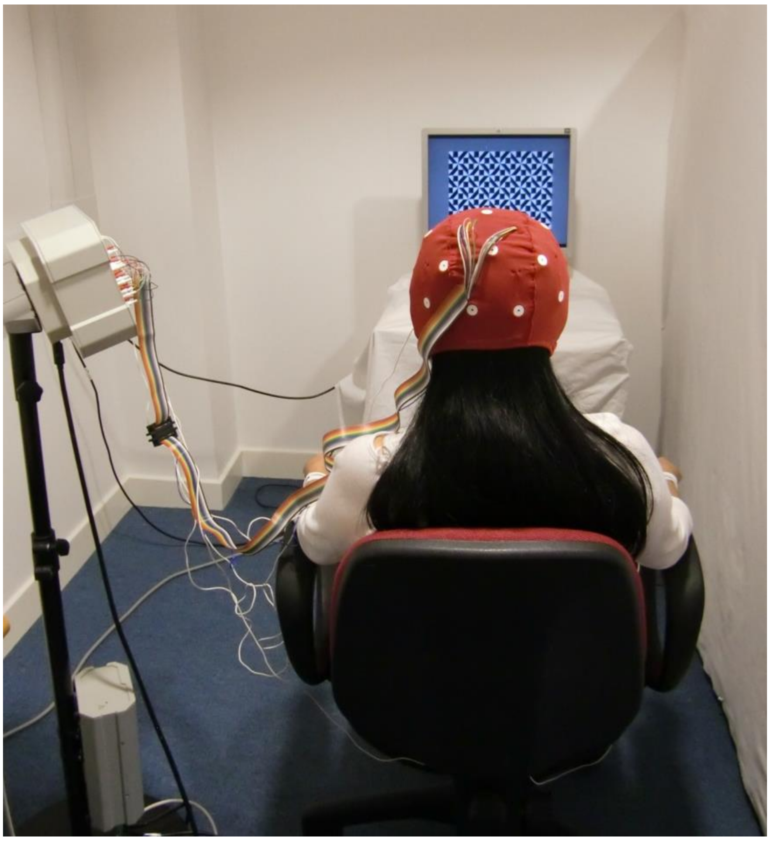


Figure 3-13 A typical experiment.

3.2.5.3 Experimental part 2

After the completion of the first experimental part, the EEG cap system and electrodes were removed from the participant. After a short break of 5 minutes, the second part of the experiment began. Firstly, the participant was given an explanation of how to use the Self-reported Rating Scales. The participant was told that the ratings of each pattern should reflect his/her immediate personal experience and that there were no right or wrong answers. He/she was given a few exercise trials until feeling confident and comfortable. Then, the slides of the second part were executed. At the end of the experiment, the participant was thanked and advised not to discuss the experiment with anyone else for avoiding influencing the results.

3.3 Data Acquisition and Processing

3.3.1 *EEG signal recordings and processing*

3.3.1.1 EEG signal recordings

Each participant's brain response was determined by EEG signals acquired through the 19 electrodes contained in the cap. The electrodes are placed on specific scalp locations in accordance with the international 10-20 system[142], as shown in Figure 3-14. The ground electrode is located in front of the Fz channel, and the reference electrode is placed on the participant's left earlobe. Each EEG signal was acquired at a sampling rate of 200 Hz and filtered by an 80Hz low pass filter. It was amplified and digitised prior to saving in output data, as shown in Figure 3-15. The electrode impedance is less than 20kΩ. The EEG system is connected with the PC through a trigger box, as shown in Figure 3-16. Once the experimental slide is displayed on the screen, the trigger box puts an event mark in the EEG signal, so that the location of the slide is accurately pinpointed along a continuous signal.

The EOG signal generated by the participant's eye movement is also recorded in the EEG system. It was acquired through the pair of bipolar electrodes. The active electrode is placed 1cm above and lateral to the corner of the left eye, and the reference electrode is placed at the participant's left mastoid. The electrodes are plugged into a bipolar polygraphic channel of the EEG system, where the EOG signal is amplified and digitised.

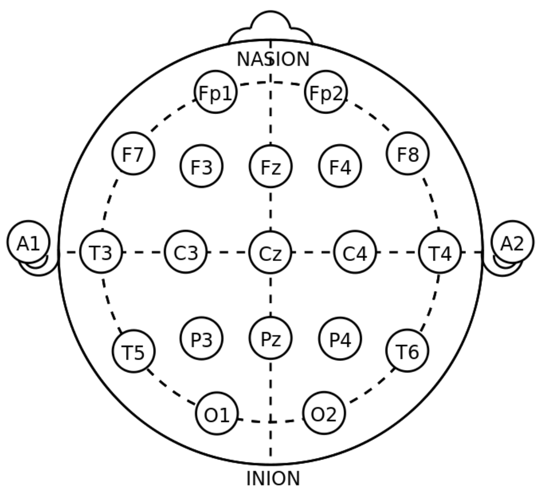
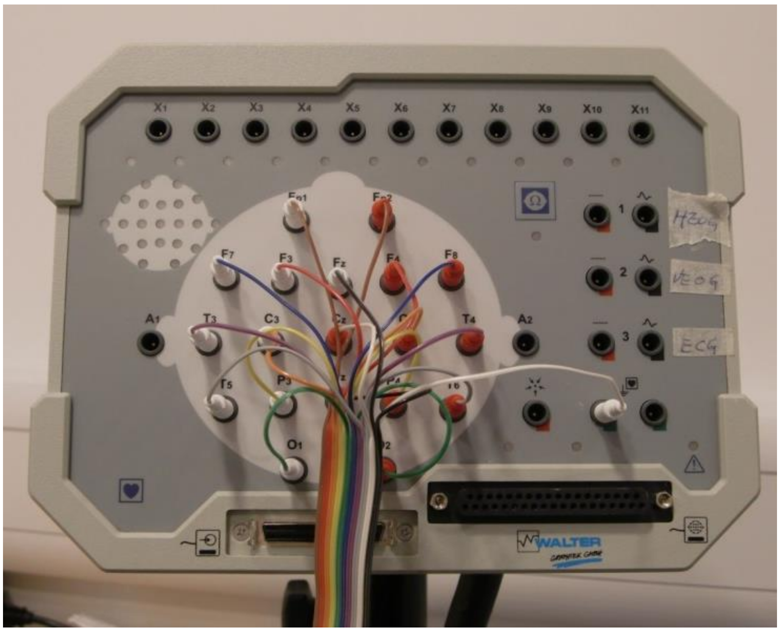


Figure 3-14 The International 10-20 system of EEG electrode placement.



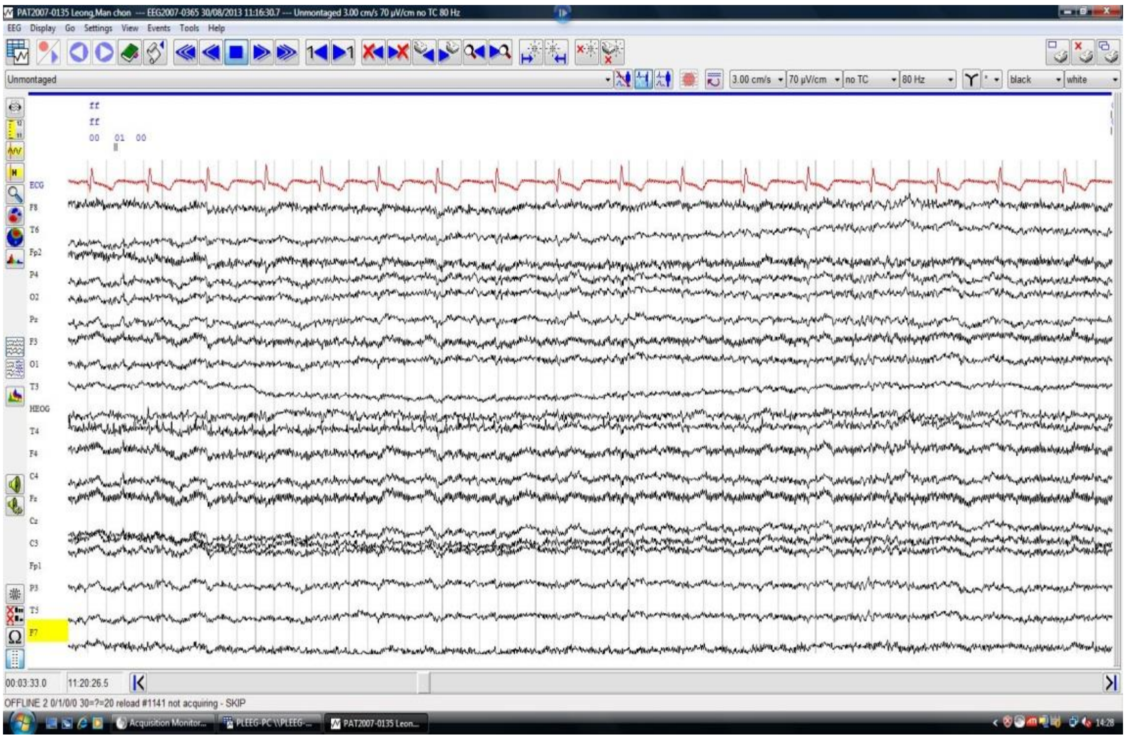


Figure 3-15 The Walter Graphtek EEG system including the PL-351 Headbox (top) and the PL-Winsor software (bottom) used in the current experiments.

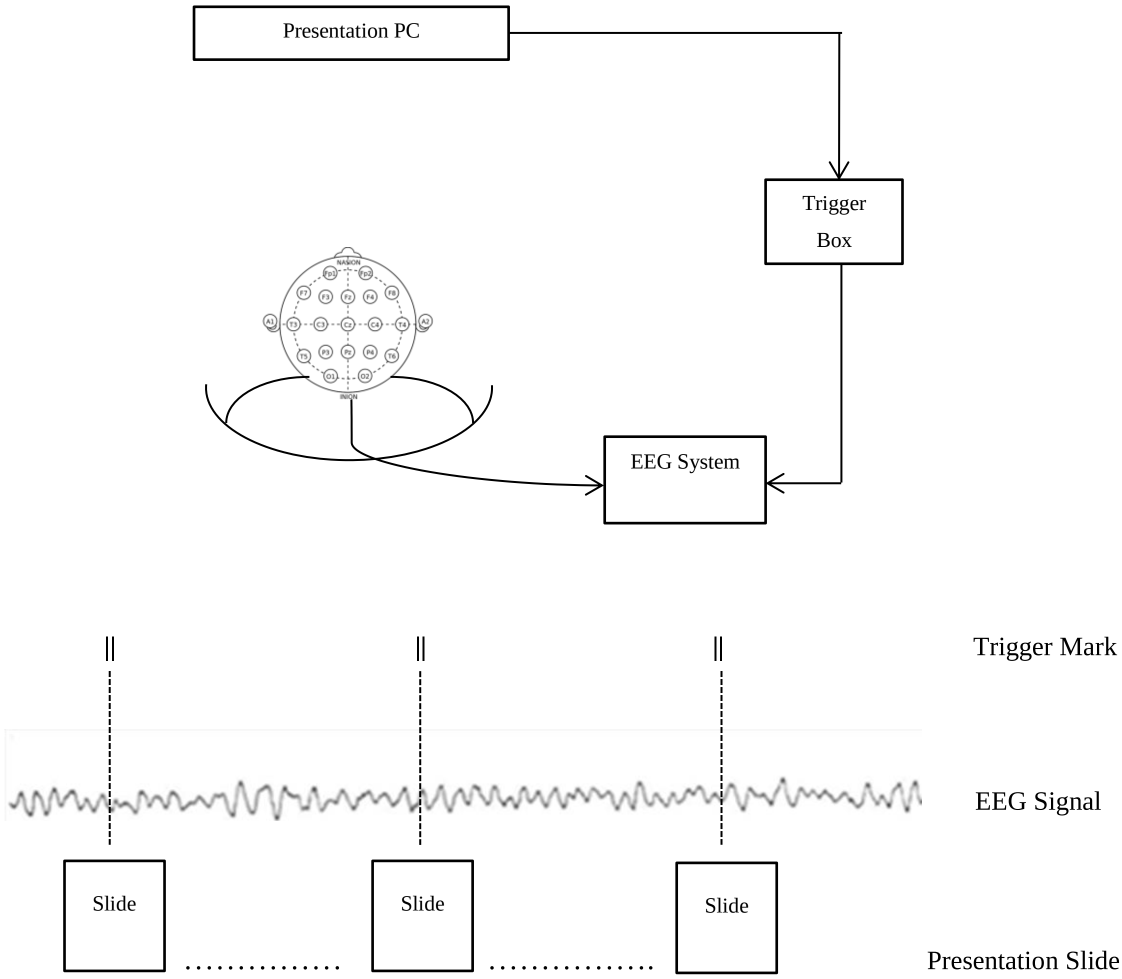


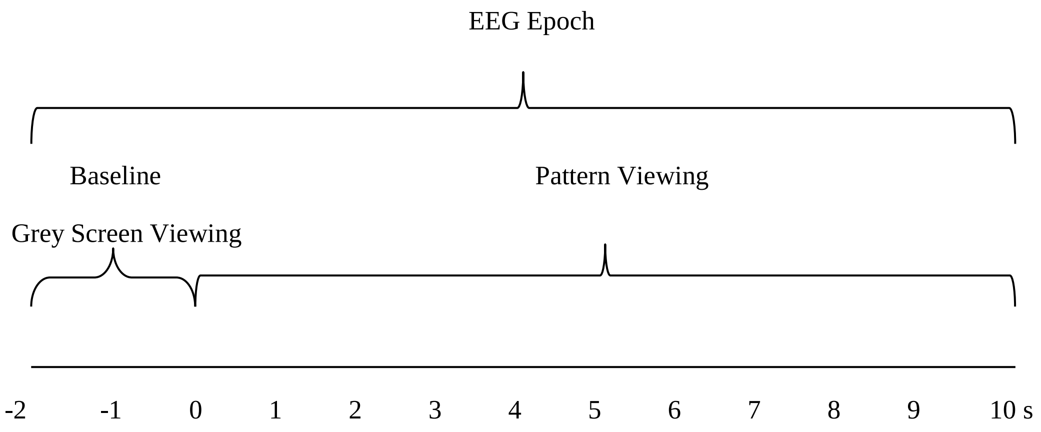
Figure 3-16 The EEG acquisition of signals during the current experiments.

3.3.1.2 EEG signal processing

During signal pre-processing, the recordings of the continuous EEG signals and the log file of the viewing slides were synchronised in the EEGLAB (version 11.0.4.3b) [6], a MATLAB toolbox. In the EEGLAB, the first viewing slide was aligned to the first trigger marker of the EEG signal, so that the viewing slides and their corresponding EEG signals were synchronous. Then, the EEG signals corresponding to the 20 pattern stimuli were extracted. Each of them contained an epoch starting 2 seconds before the pattern onset to 10 seconds after the pattern presentation on screen. Any artefact caused by possible eye movement, eyes blink, temporal muscle activity or line noise was inspected and corrected by referring to the EOG channel and using the Independent Component Analysis (ICA) method provided by the EEGLAB [6]. The ICA method is based on the assumptions that the time series recorded on the scalp are spatially stable mixtures of the activities of temporally independent EEG and artifact sources; the sum of potentials arising from different parts of the brain, scalp and body is linear at the electrodes; and the propagation delays from the sources to the electrodes are insignificant. Once the independent time course of the neutrally generated EEG and artifact sources are extracted from the data, artifact-corrected EEG signals can be obtained by removing the contributions of the artifactual sources. ICA algorithms have been proven to be capable of detecting and removing eye, muscle and line noise artefacts [143].

Hence in signal processing, the power spectral density (PSD) of the artefact-free EEG signal is calculated, and the five classic EEG waves which are Delta (1 - 3 Hz), Theta (4 - 7 Hz), Alpha (8 – 13 Hz), Beta (14 – 30 Hz) and Gamma (30 – 50 Hz) were analysed. The calculation was computed by a bespoke MATLAB script, which is reported in Appendix A.3. In the script, an EEGLAB signal processing function ‘spectopo’ was used to derive the mean log spectrum of the EEG signal of every recording channel. The ‘spectopo’ employs the MATLAB function ‘pwelch’ [144] for the power spectrum estimation. The ‘pwelch’ implements Welch’s method [145] which divides the studying signal into overlapping segments; then applies the Hamming window and computes the periodogram of each segment; and then averages the individual periodograms to obtain the PSD measurement of the signal. The output is an array of power of frequency bins. Then, the powers of the frequency bins that lie within the frequency band of each classic EEG wave are averaged to obtain the frequency band power of each wave.

Furthermore, the absolute frequency band power evoked by the pattern stimuli was obtained by subtracting the power of the baseline period from the power of the pattern viewing period, as shown in Figure 3-17. 20 participants’ absolute frequency band powers corresponding to 20 patterns were then imported to Minitab for further statistical analysis.



Absolute Frequency Band Power = Frequency Band Power $_{\text{pattern viewing}}$ − Frequency Band Power $_{\text{baseline}}$

Figure 3-17 The absolute frequency band power evoked by the pattern viewing event.

3.3.2 *ECG signal recordings and processing*

3.3.2.1 ECG signal recordings

The ECG signal of every participant was acquired through a pair of ECG electrode. The placement of the electrodes was according to one of the standard ECG limb leads placements, Lead I [146]. The negative electrode is placed on the skin above the right wrist on the inside of the arm, and the positive electrode is placed to the skin above the left wrist on the inside of the arm. Two electrodes were then plugged into a bipolar polygraphic channel on the PL-351 Headbox of the Walter Graphtek EEG system. The system performed a bipolar recording that measured the potential difference between the two electrodes. The acquired ECG signal was amplified, digitised at a 200 Hz sample rate and recorded in the EEG system.

3.3.2.2 ECG signal processing

The ECG signal processing aims at calculating the participants' instantaneous heart rate changes when responding to pattern stimulus. The heart rate is the speed of the heartbeat, defined as beats per minute (bpm). A heartbeat cycle is composed of a T wave, a QRS complex and a P wave component, as seen in Figure 3-18. The calculation of heart rate is based on the occurrence of the most prominent component of the heartbeat cycle, which is the R wave in the QRS complex. When the interval between one R wave and the next is measured, the heart rate in this period is one minute divided by the interval.

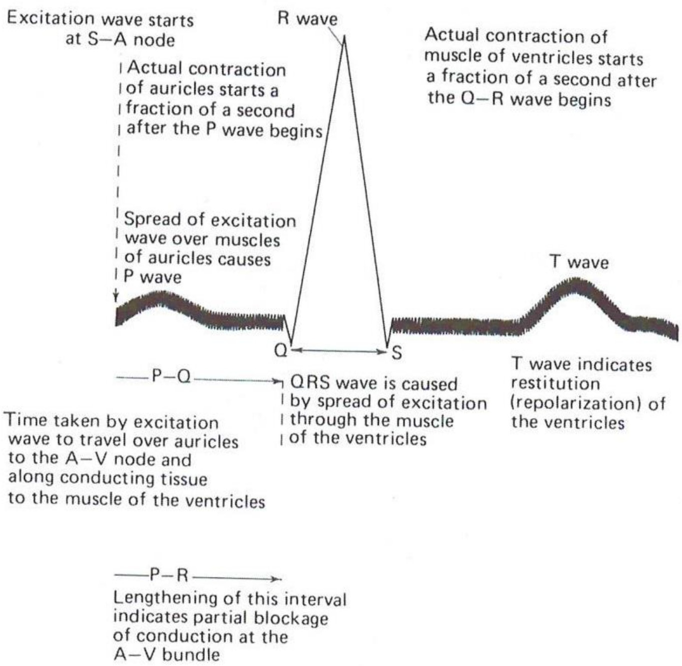
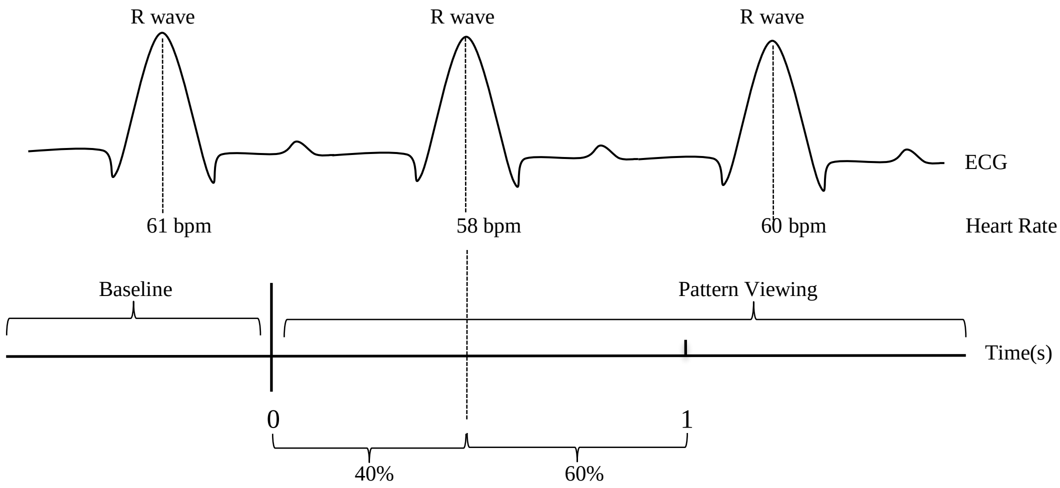


Figure 3-18 A representation of normal ECG cycle [2, p413].

In the current experiment, the heart rates of every participant were calculated from their recorded ECG signals, as shown in Figure 3-19. Firstly, the ECG signal corresponding to each pattern stimulus was extracted through the function of EEGLAB and each extracted ECG epoch started from 2 seconds before the pattern onset and ended at 10 seconds after. In each epoch, the R waves were detected by a bespoke MATLAB script, which is reported in Appendix A.4. Secondly, KARDIA version 2.4 [7] in the MATLAB toolbox was utilised to calculate the heart rate. The calculation was conducted in the baseline period and the viewing period of each pattern. In the viewing period, the heart rate was calculated every second. The one second period is defined as the one time window in the following. The heart rate of each time window was calculated by the "mean" algorithm in KARDIA. Giving an example in Figure 3-19, KARDIA converts each interval of two successive R waves to heart rate in bpm, then it measures the proportion of the time of each interval to one time window and uses the proportion to weight the contribution of the heart rate of each interval, finally summing all the weighted interval heart rates to a mean heart rate of the time window.



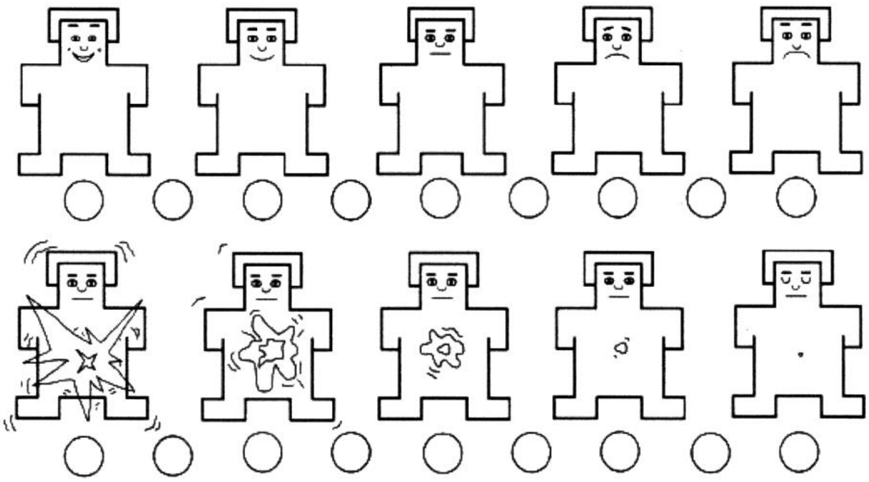
The mean heart rate of the 1st second: 40% x 58 bpm + 60% x 60 bpm = 59.2 bpm

Figure 3-19 The calculation of the heart rate in one time window.

The heart rate change corresponding to the pattern viewing event is then obtained by subtracting the heart rate of the baseline period from the heart rate of each time window in the pattern viewing period. Therefore, the final result is an array of heart rate change along 10 time windows. Lastly, each of twenty participants' heart rate changes which correspond to 20 pattern stimuli were imported to Minitab for further statistical analysis.

3.3.3 *Scoring of the Self-reported Rating Scales*

The ratings of every participant on the Self-reported Rating Scale were scored by a marking system, which gave 4 points to the left of the scale, - 4 points to the right of the scale, and a descending order from 3, 2, 1, 0, -1, -2, to -3 point for the middle circles, as shown in Figure 3-20. Accordingly, the centre circle of the scale meaning neutral response is given 0 score. The data scores were then stored into a Minitab database for further statistical analysis.



Like O O O O O O O O O **Dislike**

4 3 2 1 0 -1 -2 -3 -4

Figure 3-20 The marking system on the Self-reported Rating Scales used in the experiment.

3.4 Data Analysis and Results

3.4.1 *Data analysis method and process*

Twenty experimental patterns were separated into groups of repeating, non-repeating, weak, and intense patterns, as shown in Figures 3-3 to 3-6. Each group contains 8 patterns. The response to each group of patterns by every participant was analysed and compared.

3.4.1.1 Statistical analysis

A hypothesis is an assumption of a population parameter. This assumption may be true or not true. Statisticians use hypothesis tests [147, p139-160] to determine the probability that the given assumption is true. There are 7 steps to perform a hypothesis test as follows.

1. Decide on a null hypothesis, $H_{0.}$
2. Decide on an alternative hypothesis, $H_{1.}$
3. Decide on a significance level.
4. Calculate the appropriate test statistic, using the sample data.
5. Find the ‘p value’ on the computer output in Minitab.

6. Compare the ‘p value’ with the significance level, and decide whether to reject the null hypothesis, H_0.
7. State a conclusion, after checking to see whether the assumptions required for the test in question are valid.

In the current analysis, we assumed that there is difference in people’s responses between the repeating and non-repeating patterns, and between the weak and intense patterns. Hypothesis test was utilised to determine the probability that our assumption is true. People’s responses to the paired patterns were compared. The mean of the difference, μ, was tested. The sample data is the experimental participants’ differences obtained by the formulae as follows:

$$\text{Difference} = \text{Response}_{\text{Repeating patterns}} - \text{Response}_{\text{Non-repeating patterns}}$$

and

$$\text{Difference} = \text{Response}_{\text{Weak pattern}} - \text{Response}_{\text{Intense pattern}}.$$

According to the performing steps of the hypothesis test, the procedure in the current analysis is shown as follows.

1. H_0: $\mu = 0$. This implies that the mean of differences is zero, in other words that there is no difference between people’s responses to two paired patterns.

2. H_1: $\mu \neq 0$. This implies that the mean of difference is not equal to zero, which means there is difference between people’s responses to two paired patterns.

3. 20% significance level.

4. Perform a ‘1-Sample t-Test’ using Minitab.

5. Find the ‘p value’ on the computer output in Minitab.

6. When the computed p value is less than 0.2, we reject H_0; when the p value is over 0.2, H_0 is accepted.

7. When H_0 is rejected, we conclude that the mean difference is not zero, in other words that there is a significant difference occurring between people’s responses in the two type of tested patterns; when H_0 is accepted, it means that the mean of the difference is zero, concluding that there is no difference in people’s responses in two types of tested pattern.

There is an assumption for applying the hypothesis test, which is that the sample data are approximately normally distributed. To this effect the experimental data were tested by the Ryan-Joiner normality test which calculates the correlation between the testing data and their respective normal scores, and when the correlation coefficient is near 1.0, there is greater confidence that the testing data is normally distributed [148, p217-219]. The normality test was performed in Minitab at a significance level of 5%. When the computed p value was over 0.05, the experimental data were normally distributed. Otherwise, the odd data were inspected and deleted. Accordingly, there were no more than 20% of the data deleted in the current analysis.

Confidence interval estimation is another statistical technique used in the current analysis. Interval estimation is the use of sample data to specify a range of values bounded between two end points, within which an unknown population parameter such as the mean (μ) is asserted to lie. The confidence level is a stated proportion of confidence levels when the population mean does fall in the specified interval. Statisticians often choose a 95% confidence level and calculate a 95% confidence interval for the population mean. The 95% confidence interval describes that on 95% of confidence levels when such intervals are calculated, the population mean will lie inside the interval that is calculated from the sample data [147, p115-138]. In the current analysis, the confidence interval estimation was used to calculate the population mean of people's response to every one of the 4 types of pattern; and when a significant difference between people's responses in the two paired patterns was found, the confidence interval estimation was used to calculate the population mean of the difference. The confidence level was set at no less than 80%. During the analysis, the confidence interval estimation was performed by the 1-Sample t-Test in Minitab.

3.4.1.2 Data analysis

3.4.1.2.1 Frequency band power of the EEG

The absolute frequency band powers corresponding to pattern stimuli were computed from the EEG signal process. The data of each participant consisted of the frequency band powers of 13 out of the 19 electrode channels. The electrode channels, F7, F8, T3, T4, T5 and T6 are mainly associated with human auditory activity and hence were excluded because they are not related to this study. The analysis of the frequency power responses started with averaging each participant's frequency band power corresponding to the 8 patterns under every one of the 4 pattern types on each electrode channel. Then, the averaging powers of the two paired types were subtracted from each other. The result represented the difference in frequency power responses between the two paired types of pattern. Participants' sample data of the difference were then used to calculate the population mean of the difference through statistical analysis as already stated.

3.4.1.2.2 The Frontal Alpha Asymmetry index

According to the frontal EEG asymmetry model, the experience of an approach oriented, positive response is associated with the brain's left hemisphere dominance, such as a greater relative left hemisphere activation in the frontal and prefrontal area; whilst the experience of a negative withdrawal response is associated with the right hemisphere's dominance, such as a greater relative right hemispheric activation in the frontal and prefrontal area. The hemispheric activation is measured by the Alpha band power of the EEG signal. The Alpha power and the brain activity are inversely related, which means that a decrease in Alpha power indicates an increase in brain activity. Therefore, the hemispheric activation in the frontal and prefrontal cortex can be measured by the frontal Alpha asymmetry index, which was obtained by subtracting the average of the left frontal Alpha power from the average of the right frontal Alpha power. The positive value of the index shows that the right hemisphere has relatively higher Alpha power, so that the left hemisphere is in dominance, which indicates a positive response to the pattern. The negative value of the index shows that the left hemisphere has relatively higher Alpha power, so that the right hemisphere is in dominance, which indicates an experience of negative response to the pattern. When the value of the index is zero, it means that there is a neutral oriented response, hence neutral response to the pattern.

The Frontal Alpha Asymmetry index was obtained by subtracting the averaging Alpha power of the left hemisphere from the averaging Alpha power of the right hemisphere, using the following formula.

$$\text{Alpha Asymmetry Index} = \text{Alpha Power } (F8 + Fp2 + F4) / 3 - \text{Alpha Power } (F7 + Fp1 + F3) / 3$$

The power of the right frontal hemisphere was averaged from the powers of the F8, Fp2 and F4 electrode channels; the power of the left frontal hemisphere was average from the power of the F7, Fp1 and F3 electrode channels. The participants' Frontal Alpha

Asymmetry index to every one of the 4 pattern types was the average of his/her Frontal Alpha Asymmetry indices of the 8 patterns in each type. Then, the population mean of the Frontal Alpha Asymmetry index was calculated by using confidence interval estimation. The significant result of the mean of the index was then analysed.

3.4.1.2.3 Heart rate changes

The data analysis of the heart rate changes corresponding to the pattern stimuli has two levels. At the first level, it estimates people's heart rate changes when responding to every one of the 4 pattern types. During this process, each participant's heart rate changes to each type of pattern were obtained by averaging his/her heart rate changes for the 8 patterns of each of the 4 types. Then, the population mean of the heart rate change was estimated by confidence interval estimation based on twenty participant's sample data. At the second level, people's heart rate changes corresponding to two paired types of pattern were compared and the population mean of the difference was estimated by the hypothesis test technique. The comparison and estimation were conducted on each time window. When a significant difference was observed, the mean of the difference was studied through statistical analysis as already stated.

3.4.1.2.4 Self-reported Rating Scores

In the data analysis, every participant's rating score on each scale to every one of the 4 types of pattern was obtained by averaging the scores of the 8 patterns of each pattern type. The population mean of the rating score was calculated by the confidence interval estimation. Then, the difference between the rating scores of the two paired pattern types was investigated through statistical analysis as already stated.

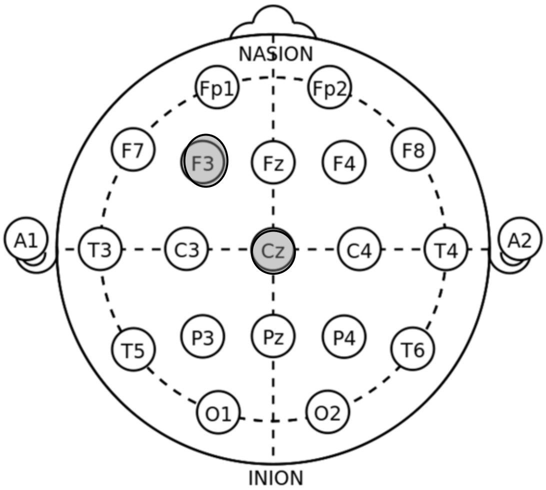
3.4.2 *Investigating the differences in people's responses to repeating and non-repeating patterns*

3.4.2.1 Frequency band power of the EEG

The differences of the 5 frequency band powers of twenty participants when responding to the repeating and non-repeating patterns are reported in Appendices A.5 – A.9. The observed significant differences of each frequency band are reported as follows.

- Delta frequency power

Significant differences in Delta power response were found in the Cz and F3 channels, as shown in Figure 3-21. In the Cz channel location, the mean of the difference at 90% confidence level lies in between -1.007 and -0.002. This shows that the repeating patterns triggered less Delta power than the non-repeating patterns at the central region of the brain. In the F3 channel location, the interval of the mean of the difference at 84% confidence level are over zero, which shows that the repeating patterns evoked a higher Delta frequency power than the non-repeating patterns at the left frontal region of the brain. In studies of emotional response, the Delta power has been found to be higher in response to emotional stimuli than neutral stimuli [149]. However, current results show that the non-repeating patterns evoke higher Delta power in the Cz location of the brain, whilst the repeating patterns trigger higher Delta power in the F3 location. Therefore, no conclusion can be made from the current results.



Variable	N	Mean	StDev	SE Mean	84% CI	T	P
F3	20	0.644	1.924	0.430	(0.015, 1.273)	1.50	0.151

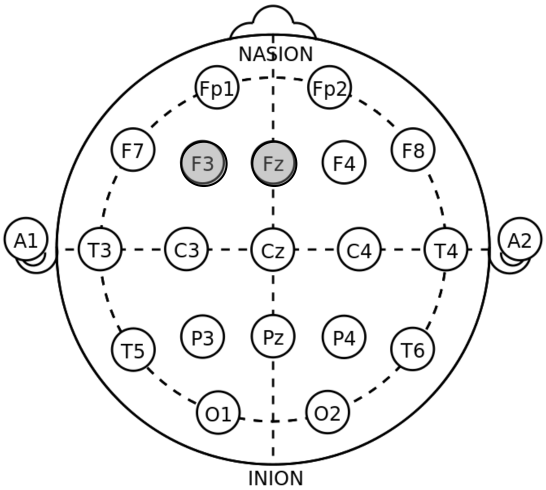
Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Cz	16	-0.504	1.147	0.287	(-1.007, -0.002)	-1.76	0.099

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 3-21 Significant differences of the brain's Delta power, when responding to repeating and non-repeating patterns.

- Theta frequency power

Significant differences in Theta power response were found in the frontal lobe of the brain, as seen in Figure 3-22. In the F3 channel location, repeating patterns triggered a higher Theta frequency power than non-repeating patterns at 81% confidence level. In the Fz channel location, repeating patterns also evoked a higher Theta frequency power at 86% confidence levels. The increased Theta power in the frontal region of the brain has been observed in an association with emotional expression compared with neutral expression [150], and the frontal midline Theta has been found that it has positively correlated with the pleasantness of the emotional experience [151]. In the current investigation, the significant difference in the frontal region of the brain might infer that the repeating patterns indicate a more pleasant effect in people's emotional response.



Variable	N	Mean	StDev	SE Mean	81% CI	T	P
F3	20	0.433	1.414	0.316	(0.004, 0.863)	1.37	0.187

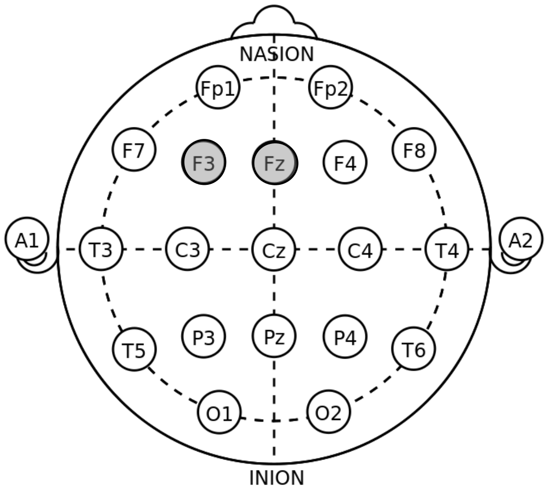
Variable	N	Mean	StDev	SE Mean	86% CI	T	P
Fz	20	0.440	1.275	0.285	(0.001, 0.879)	1.54	0.139

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 3-22 Significant differences of the brain's Theta power, when responding to repeating and non-repeating patterns.

- Alpha frequency power

Significant differences in Alpha power response were found in the frontal lobe of the brain at the locations of the F3 and Fz channels. The statistical testing results, as shown in Figure 3-23, show that the mean of the difference is less than zero at 85% confidence level in F3 channel and 95% confidence level in Fz channel. They indicate that the repeating patterns evoke less Alpha power than the non-repeating patterns in these two locations of the brain. In the literature, the Alpha power response and emotional process mainly focus on EEG frontal Alpha asymmetry, therefore the observation is analysed in the following section of the Frontal Alpha Asymmetry index.



Variable	N	Mean	StDev	SE Mean	85% CI	T	P
F3	18	-0.269	0.753	0.178	(-0.537, -0.001)	-1.51	0.148

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Fz	20	-0.544	1.056	0.236	(-1.038, -0.050)	-2.31	0.033

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

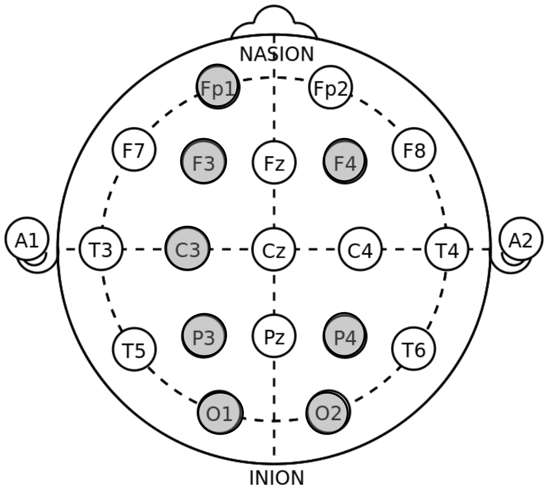
Figure 3-23 Significant differences of the brain's Alpha power, when responding to repeating and non-repeating patterns.

- Beta frequency power

There was no significant difference in Beta power response evoked between repeating and non-repeating patterns.

- Gamma frequency power

Significant differences in Gamma power response were observed in different locations of the brain in the participants. They were the Fp1, F3 and F4 channels located in the frontal lobe; the C3 channel in the central sulcus; the P3 and P4 channels in the parietal lobe; and the O1 and O2 channels in the occipital lobe of the brain. The statistical testing results are shown in Figure 3-24. The mean of the difference in the Fp1, F3 and F4 channels is over zero at 80% confidence level. It indicates that repeating patterns evoked higher Gamma powers than non-repeating patterns in the left of the pre-frontal lobe and at both sides of the frontal lobe. The mean of the difference is less than zero at 95% confidence level in the C3 channel, which shows that repeating patterns evoked less Gamma power in this location of the brain than non-repeating patterns. The mean of the difference in the P3 and P4 channels is less than zero at over 80% confidence levels. It shows that repeating patterns evoke less Gamma power in these areas of the parietal lobe. In the occipital lobe: the visual brain, the results show that the mean of the difference is less than zero at high significance levels 95% and 93%, which shows that repeating patterns evoke less Gamma power than non-repeating patterns in the visual brain. The Gamma power response in the occipital region of the brain has been found to be increased in response to unpleasant stimuli [152]. In the current investigation, the significant difference observed in the occipital lobe might infer that the non-repeating patterns evoked an unpleasant effect on people's emotional response. The increased Gamma power has also been found to be associated with negative emotional expression such as anger and fear compared with the neutral expression [153], and higher Gamma response has been also found to be elicited by negative emotional stimulation [80, 154]. In the current observation, the significant difference found in the parietal and central regions of the brain might infer that non-repeating patterns evoked a negative emotional response. Although the differences in the frontal area of the brain show that repeating patterns evoked a higher Gamma response, the confidence level of these results is lower than the one in the posterior of the brain, therefore it is less significant. Therefore, the results found in the posterior of the brain might infer that non-repeating patterns have an unpleasant effect on people's emotion response.



Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Fp1	20	0.472	0.580	0.130	(0.201, 0.743)	3.64	0.002

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
F3	19	0.257	0.730	0.168	(0.005, 0.509)	1.53	0.143

Variable	N	Mean	StDev	SE Mean	87% CI	T	P
F4	20	0.257	0.726	0.162	(0.000, 0.514)	1.59	0.129

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
C3	17	-0.282	0.477	0.116	(-0.527, -0.037)	-2.44	0.027

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
P3	18	-0.476	0.451	0.106	(-0.700, -0.252)	-4.48	0.000

Variable	N	Mean	StDev	SE Mean	82% CI	T	P
P4	20	-0.147	0.472	0.105	(-0.294, -0.000)	-1.40	0.179

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
O1	20	-0.337	0.702	0.157	(-0.666, -0.009)	-2.15	0.045

Variable	N	Mean	StDev	SE Mean	93% CI	T	P
O2	20	-0.256	0.574	0.128	(-0.502, -0.009)	-1.99	0.061

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 3-24 Significant differences of the brain's Gamma power, when responding to repeating and non-repeating patterns.

3.4.2.2 The Frontal Alpha Asymmetry index

The Frontal Alpha Asymmetry indices of the twenty participants corresponding to repeating and non-repeating patterns are reported in Appendices A.10 – A.11. The confidence intervals of the mean of the Frontal Alpha Asymmetry index of the patterns are presented in Figure 3-25, where a significant mean of the index of the repeating patterns has been found. A confidence interval estimation with 90% confidence level shows the following:

Mean = 0.255,

Standard Deviation = 0.649,

Standard Error of the Mean = 0.145,

Confidence intervals between 0.004 and 0.506.

The interval of the mean is over zero, which shows that the mean of the Frontal Alpha Asymmetry index is a positive value at 90% confidence level. It is therefore established that the viewer's left hemisphere is dominant since the right frontal hemisphere has a higher Alpha power. According to the frontal EEG asymmetry theory, the left dominance of the brain activation reflects an approach oriented response, revealing that people have significant positive responses and preference to the regularly repeating patterns. However, in the case of the non-repeating patterns, the mean of the Frontal Alpha Asymmetry index is undefined, neither positive nor negative, and therefore it has no significance, revealing no population preference in non-repeating patterns.

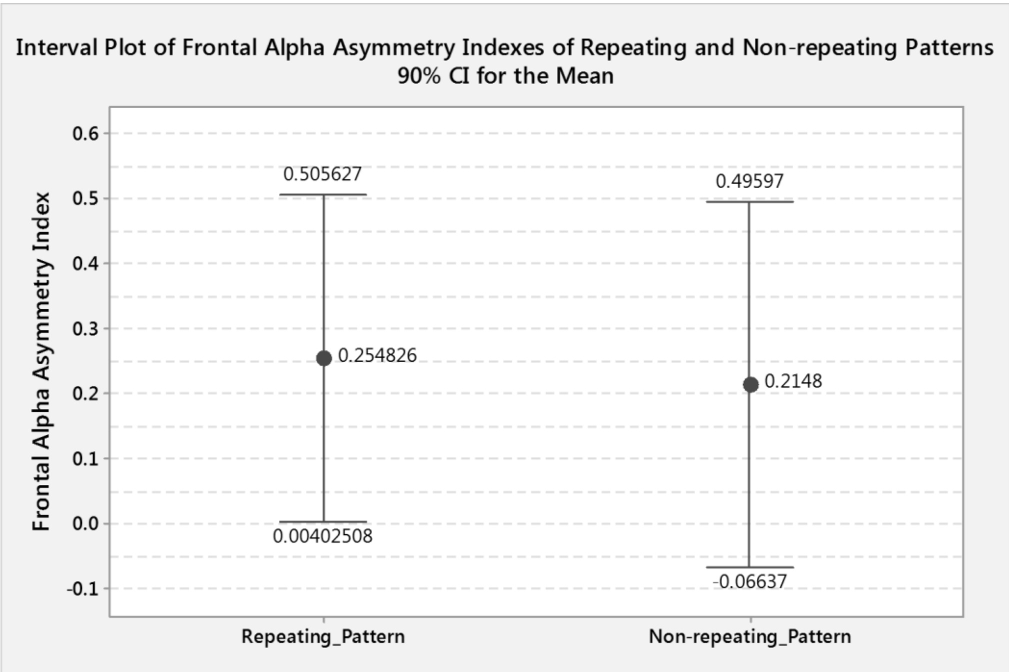


Figure 3-25 The Frontal Alpha Asymmetry brain indices of the repeating and non-repeating patterns.

3.4.2.3 Heart rate changes

The heart rate changes of the twenty participants in each time window when responding to repeating and non-repeating patterns are reported in Appendices A.12 – A.13. The mean of the heart rate change to the repeating patterns was calculated and the statistical results are presented in Figure 3-26. At 80% confidence level of the mean, the interval of the mean of each time window is less than zero. This indicates that people's heart rate response to repeating patterns was a deceleration compared to the baseline heart rate. The mean of heart rate change responding to the viewing of non-repeating patterns are reported in Figure 3-27. At 80% confidence level, the interval of the mean of each time window is less than zero. Therefore, people's heart rate response to non-repeating patterns was also a deceleration compared to the baseline heart rate. The difference of the two heart rate decelerations between repeating and non-repeating patterns was calculated by hypothesis test. The sample data of twenty participants are reported in Appendix A.14. At 80% confidence level, the mean of the difference of each time window is presented in Figure 3-28. Significant differences were observed on the first 4 time windows, on the 8th and the 10th time windows. The mean of the difference of the first 4 time windows is over zero. This indicates that people's initial heart rate deceleration is smaller when viewing the repeating patterns than the non-repeating patterns. In the 8^{th} and 10^{th} second windows, the mean of the difference is less than zero, which shows that the heart rate deceleration was larger for the repeating patterns than for the non-repeating patterns. A greater heart rate deceleration has been found to be associated with the response to unpleasant stimulation [155, 156]. Therefore, in the current investigation, the significant difference in the initial 4 second heart rate change might infer that the non-repeating patterns might trigger an unpleasant effect on people's valence response.

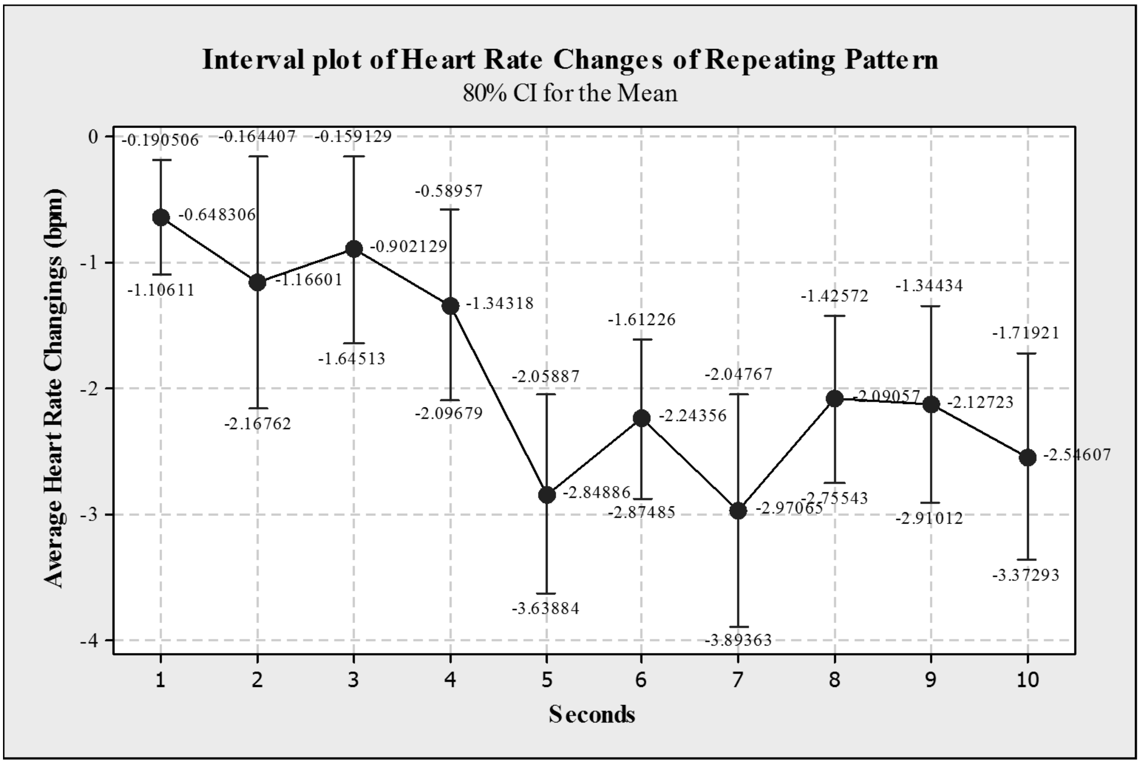


Figure 3-26 People's heart rate changes responding to the viewing of repeating patterns.

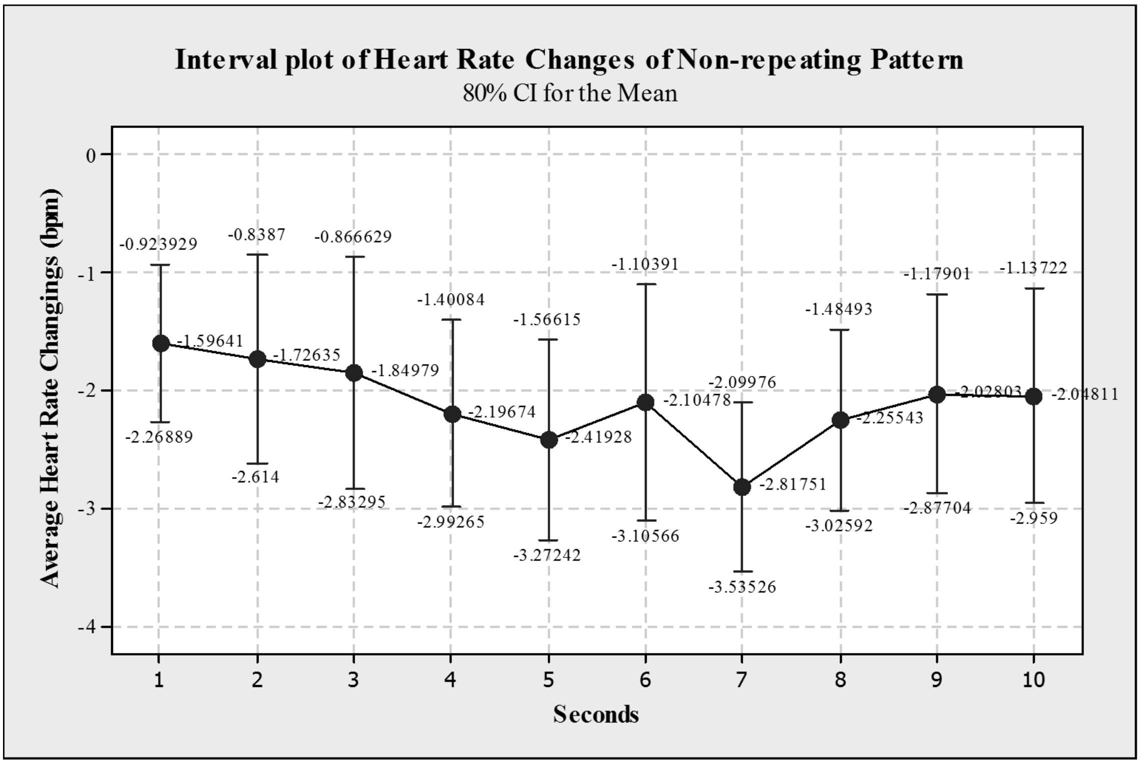


Figure 3-27 People's heart rate changes responding to the viewing of non-repeating patterns.

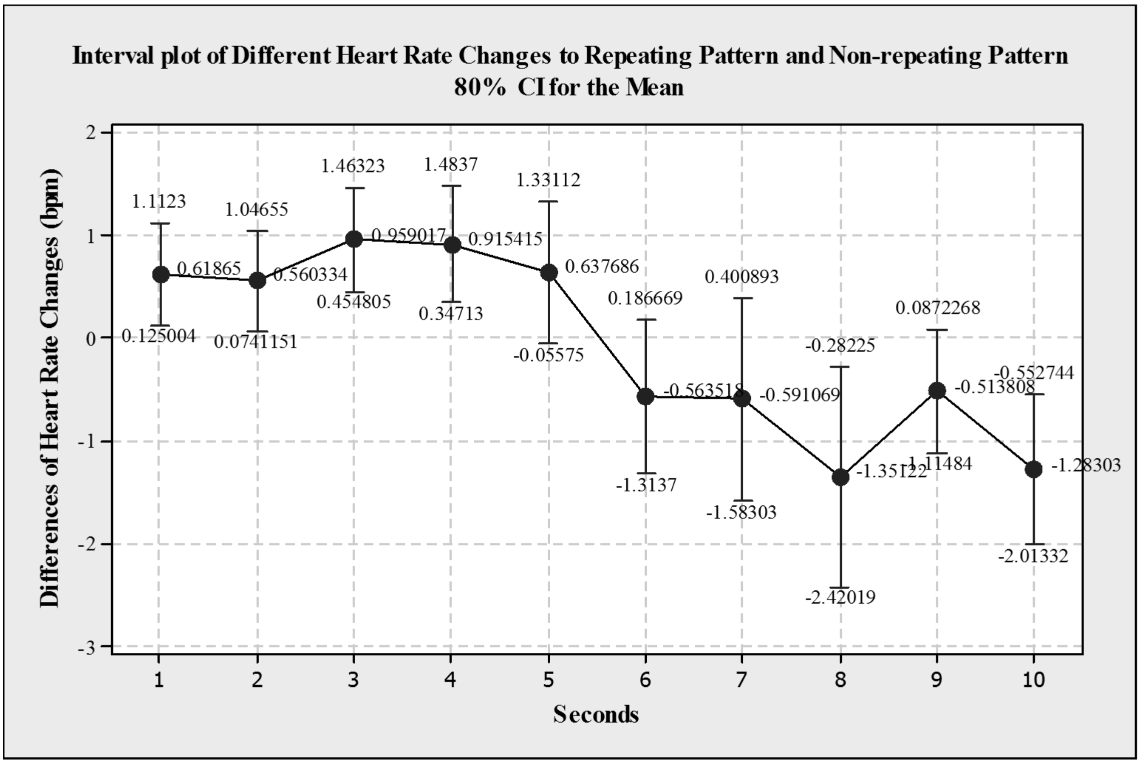


Figure 3-28 The differences of people's heart rate changes when viewing repeating and non-repeating patterns.

3.4.2.4 Subjective analysis

The average rating scores by the twenty participants of the Valence, Arousal and Likert scales to the repeating and non-repeating patterns are reported in Appendices A.15 – A.17. One participant's rating scores on the three scales were removed because it was found to be unsuitably biased. The mean of the rating score of every scale was calculated by confidence interval estimation at 95% confidence level and the results are presented in Figure 3-29. In the Valence scale a significant result was observed in the repeating patterns. The confidence interval estimation of the mean of the rating score shows the following:

Mean = 0.743,

Standard Deviation = 0.846,

Standard Error of the Mean = 0.194,

Confidence interval between 0.336 and 1.151.

The interval of the mean of the rating score is over zero, which shows that the repeating patterns was rated to have a positively pleasant effect on people's emotional response. In the case of non-repeating patterns, the mean of the rating score is undefined neither positive nor negative, and therefore it has no significance, revealing no population pleasant response to non-repeating patterns.

In the Arousal scale a significant result was found in the non-repeating patterns. The confidence interval estimation of the mean of the rating score shows the following:

Mean = 0.493,

Standard Deviation = 0.879,

Standard Error of the Mean = 0.202,

Confidence interval between 0.070 and 0.917.

The interval of the mean is both over zero, which shows that the non-repeating patterns were rated to have an exciting effect on people's emotional response. In the case of repeating patterns, the mean of the rating score is undefined neither positive nor negative, and therefore it has no significance, revealing no population exciting response to repeating patterns.

In the Likert scale, a significant result was found in both patterns. The confidence interval estimation of the mean of the rating score of repeating patterns shows the following:

Mean = 0.711,

Standard Deviation = 0.980,

Standard Error of the Mean = 0.225,

Confidence interval between 0.238 and 1.183.

The confidence interval estimation of the mean of the rating score of non-repeating patterns shows the following:

Mean = 0.479,

Standard Deviation = 0.754,

Standard Error of the Mean = 0.178,

Confidence interval between 0.104 and 0.854.

The intervals of the mean of the repeating and non-repeating patterns were both over zero, which shows that both patterns were rated to have a positive preference.

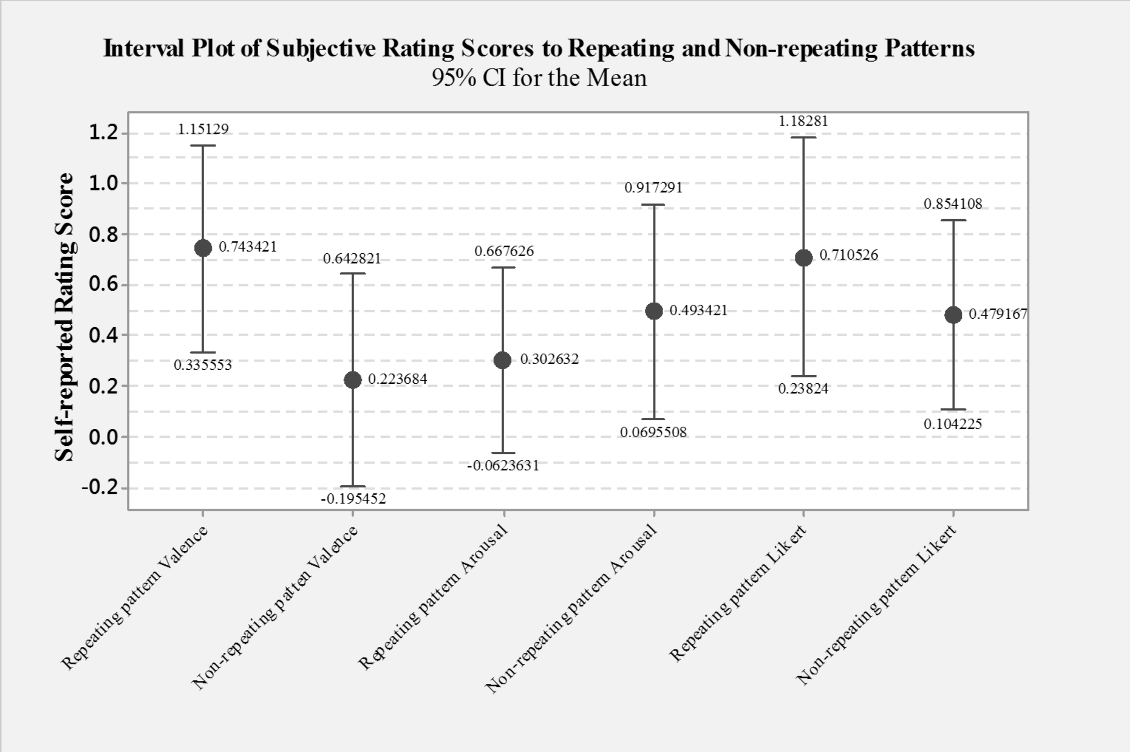


Figure 3-29 People's subjective rating scores when viewing repeating and non-repeating patterns.

The difference between the rating scores of the repeating and non-repeating patterns was calculated. At the 90% confidence level, the mean of the difference is presented in Figure 3-30. The significant difference was only observed in the Valence scale. A confidence interval estimation with 90% confidence level shows the following:

Mean = 0.520,

Standard Deviation = 1.198,

Standard Error of the Mean = 0.275,

Confidence interval between 0.043 and 0.996, T=1.89 and p-value=0.075.

It can therefore be concluded that the repeating patterns are rated as more pleasant than the non-repeating patterns at a significantly high confidence level at 90%. In the

Arousal and Likert scales, the mean of the difference is undefined neither positive nor negative and therefore it has no significant difference, revealing no difference in people's arousal response or preference between the repeating and non-repeating patterns.

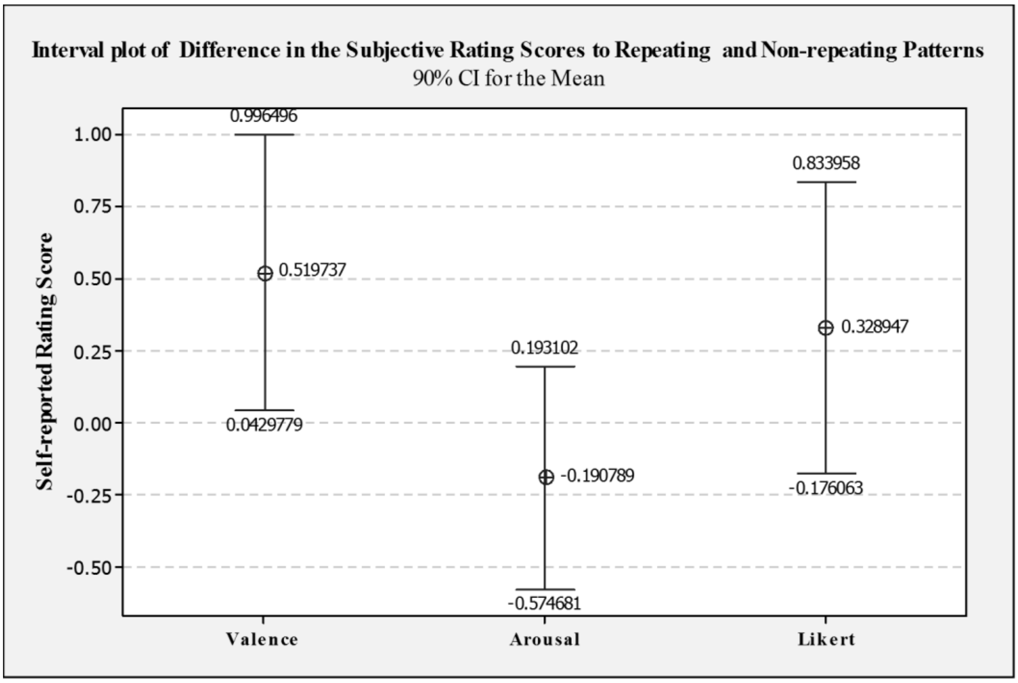


Figure 3-30 People's difference in the subjective rating scores when viewing repeating and non-repeating patterns.

3.4.2.5 Result interpretation summary

The most significant difference observed in the current experiment is that repeating patterns have a pleasant effect on people's emotional response and as opposed to the non-repeating patterns. The result is established by analysing people's subjective evaluation, their brain waves and their cardiac reactions. In the subjective evaluation, the repeating patterns had a significant result on the Valence scale. At 95% confidence level, the mean of the rating scores is over zero, which shows that the repeating patterns were rated to have a pleasant effect. However, there is no significant result for the non-repeating patterns at the same confidence level. In the comparison of the rating scores on the Valence scale between the repeating and non-repeating patterns, at 90% confidence level, the mean of the difference is over zero with p-value at 0.075. This shows that the rating score of the repeating patterns is significantly higher than the rating score of the non-repeating patterns. Therefore, the findings from the subjective evaluation show people consciously consider the repeating patterns as more pleasant than non-repeating patterns. The significant difference in the Theta power response of the brain waves shows that the repeating patterns triggered a higher Theta power on the Fz channel. The Theta power response has been reported to occur in different mental states and cognitive activities. Regarding the emotional process, frontal midline Theta has been found that it has positively correlated with the pleasantness of the emotional experience. Therefore, the current observation indicates that the repeating patterns have a pleasant effect on people's emotional response, which is in an agreement with a similar study of the frontal midline Theta power and emotional response [77]. In measurement of the Gamma power of the brain waves, the significant differences were found on both sides of the occipital region of the brain at 95% and 93% confidence levels, which shows that non-repeating patterns evoked significantly higher Gamma power than repeating patterns in the occipital region of the brain. The Gamma power in the occipital region of the brain has been found to be increased in response to unpleasant emotional simulation. Therefore, the current investigation might indicate that non-repeating patterns have an unpleasant effect on people's emotional response compared with repeating patterns. Furthermore, in the measurement of the Frontal Alpha Asymmetry index, the repeating patterns have a positive index value at 90% confidence level, which indicates that people processed positive, approach-related emotions when responding to repeating patterns; whereas no significant value was found in the Frontal Alpha Asymmetry index of non-repeating patterns.

Additionally, the investigation of people's different cardiac responses between repeating and non-repeating patterns has shown non-repeating patterns have an unpleasant effect in people's emotional response. People had heart rate deceleration when responding to both types of pattern. The heart rate deceleration was larger for the non-repeating patterns than the repeating patterns in the initial 4 seconds of the heart rate response. A greater heart rate deceleration has been found to be associated with the response to unpleasant stimulation. Therefore the current observation indicates that non-repeating patterns have more negative effect on people's valence response than repeating patterns, which has agreed with people's subjective evaluation. This result is consistent with similar studies [155, 156] in literature.

Overall, people's physiological reactions fit well with their subjective evaluations, in which repeating patterns have significantly more pleasant effect than the non-repeating patterns and evoke a positive emotional experience as a result of positive preference.

3.4.3 *Investigating the differences in people's responses to weak and intense patterns*

3.4.3.1 Frequency band power of the EEG

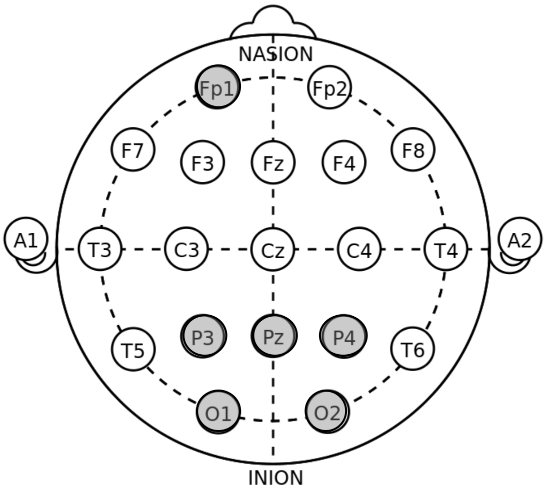
The differences of twenty participants' frequency band powers of their brain responding to the viewing of weak and intense patterns are reported in Appendices A.18 – A.22. The observed significant differences of each frequency band are reported as follows.

- Delta frequency power

There is no significant difference found in people's Delta power response to the weak and intense patterns.

- Theta frequency power

Significant differences in Theta power responses were found in the locations of prefrontal, parietal and occipital lobes of the brain. The results are shown in Figure 3-31. On the Fp1 channel, the interval of the mean of the difference, at 95% confidence level, is below zero at the minus scale, which shows that the weak patterns evoked less Theta frequency power than the intense patterns in this location. Over the partial lobe at the P3, Pz and P4 electrode channels, the interval of the mean of the difference is less than zero, which indicates that the weak patterns evoked less Theta power than the intense patterns in this area of the brain. Over the visual brain at O1 and O2 channels, the mean of the difference is also below zero in the minus scale, which shows that the weak patterns triggered less Theta frequency power than the intense patterns in this area of the brain. The Theta power in the posterior brain regions has been found to be triggered by affective emotional stimuli compared with neutral stimuli [157]. The result of the current investigation might infer that the intense patterns are more affective on people's emotional response than the weak patterns.



Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Fp1	18	-0.456	0.880	0.207	(-0.894, -0.019)	-2.20	0.042

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
P3	20	-0.634	1.302	0.291	(-1.244, -0.025)	-2.18	0.042

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
Pz	20	-0.446	1.307	0.292	(-0.885, -0.007)	-1.53	0.144

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
P4	20	-0.762	1.454	0.325	(-1.442, -0.081)	-2.34	0.030

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
O2	20	-0.862	1.061	0.237	(-1.358, -0.366)	-3.63	0.002

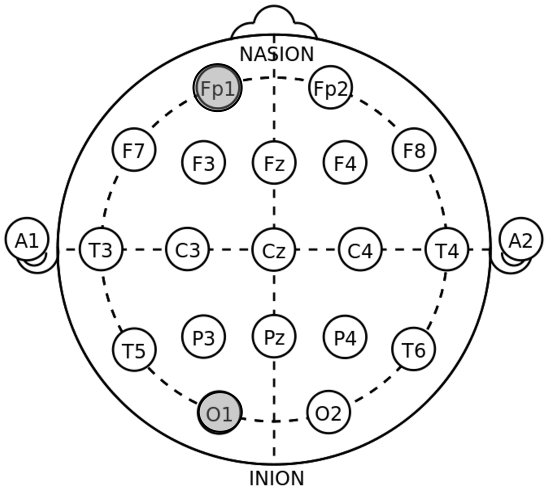
Variable	N	Mean	StDev	SE Mean	95% CI	T	P
O1	20	-0.588	1.081	0.242	(-1.094, -0.082)	-2.43	0.025

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 3-31 Significant differences of the brain's Theta power, when responding to weak and intense patterns.

- Alpha frequency power

Significant differences in Alpha frequency power response were found in two electrode channels as seen in Figure 3-32. At the Fp1 channel located in the left of the prefrontal lobe, the interval of the mean of the difference is less than zero. This shows that the weak patterns evoked less Alpha power than intense patterns in this location. At the O1 electrode channel located in the left of the occipital lobe, the interval of the mean of the difference is less than zero. This indicates that the weak patterns evoked less Alpha power than the intense patterns in this location of the brain. The relation between emotional process and the Alpha power response at the occipital lobe of the brain has not been found in literature. Therefore, no inference is made from the finding at the O1 channel. The observation of Alpha power response in the frontal lobe was analysed in the following section of the Frontal Alpha Asymmetry index.



Variable	N	Mean	StDev	SE Mean	80% CI	T	P
Fp1	18	-0.302	0.949	0.224	(-0.600, -0.004)	-1.35	0.195

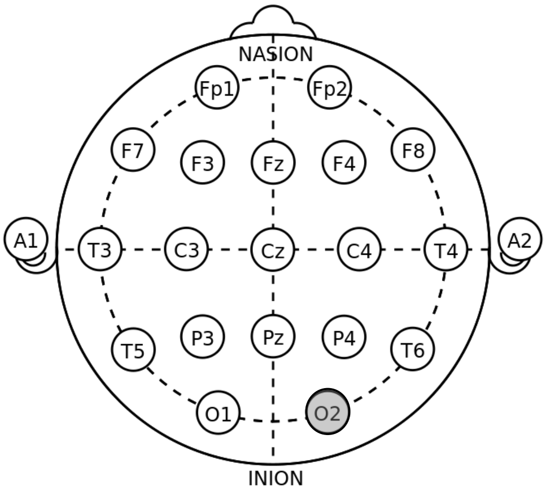
Variable	N	Mean	StDev	SE Mean	93% CI	T	P
O1	17	-0.411	0.871	0.211	(-0.821, -0.001)	-1.95	0.069

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 3-32 Significant differences of the brain's Alpha power, when responding to weak and intense patterns.

- Beta frequency power

Significant difference in the Beta power response was only observed in the O2 channel shown in Figure 3-33. The interval of the mean of the difference is less than zero, which shows that the weak patterns evoked less Beta power than the intense patterns in this area of the visual brain. In literature, the connection between Beta power response in the occipital lobe of the brain and human emotional process is unclear. Therefore, no conclusion is made from this result.



Variable	N	Mean	StDev	SE Mean	80% CI	T	P
O2	19	-0.271	0.848	0.194	(-0.529, -0.012)	-1.39	0.181

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 3-33 Significant differences of the brain's Beta power, *when responding to weak and intense patterns.*

- Gamma frequency power

There is no significant difference found in the Gamma power response between weak and intense patterns.

3.4.3.2 The Frontal Alpha Asymmetry index

The Frontal Alpha Asymmetry indices of twenty participants' corresponding to the weak and intense patterns are reported in Appendices A.23 – A.24. The confidence intervals of the mean of the Frontal Alpha Asymmetry index of the patterns is presented in Figure 3-34, where a significant mean of the index of the weak patterns has been found. A confidence interval estimation with 90% confidence level shows the following:

Mean = 0.208,

Standard Deviation = 0.537,

Standard Error of the Mean = 0.120,

Confidence interval between 0.001 and 0.416.

The interval of mean of the index is over zero, which shows that the mean of the Frontal Alpha Asymmetry index is a positive value at 90% confidence level. It is therefore established that people's left hemisphere is dominant since the right frontal hemisphere has a higher Alpha power. According to the frontal EEG asymmetry theory, the left dominance of the brain activation reflects a positive approach response, revealing that people have significant positive response to the weak patterns. However, there is no significant mean of the index of the intense patterns. The mean of the Frontal Asymmetry index is undefined neither positive nor negative, and therefore it has no significance, showing no population response to the intense patterns.

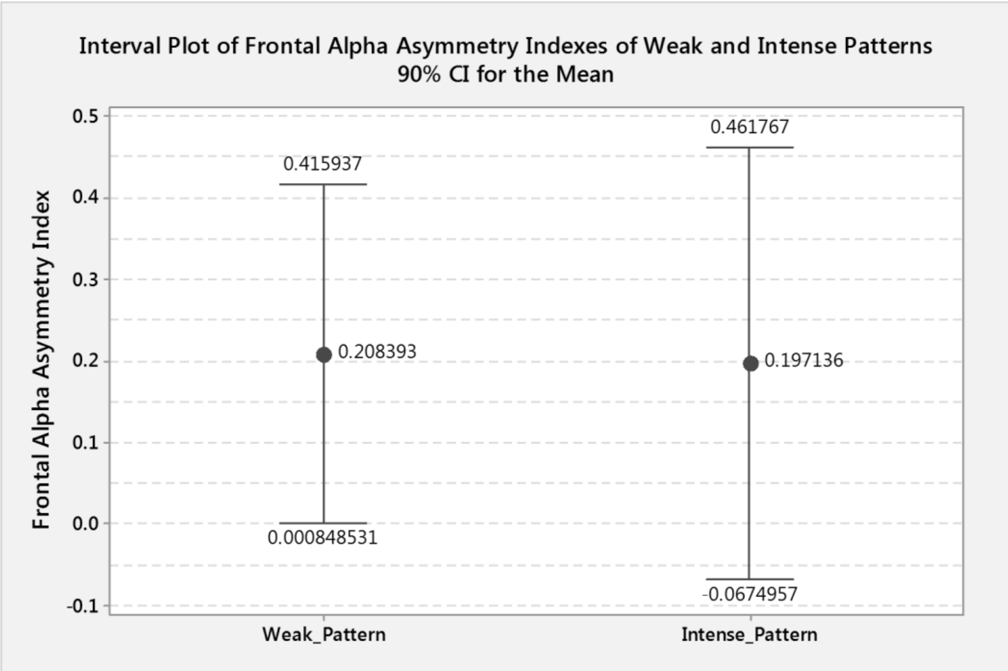


Figure 3-34 The Frontal Alpha Asymmetry brain indices of the weak and intense patterns.

3.4.3.3 Heart rate changes

The heart rate changes of the twenty participants in each time window when responding to the weak and intense patterns are reported in Appendices A.25 – A.26. The mean of the heart rate changes to the weak patterns was calculated and the statistical results are presented in Figure 3-35. At 80% confidence level, the mean of heart rate change in each time window is less than zero, which shows that people's heart rate response to weak patterns is a deceleration compared to the baseline heart rate. The same result was observed at 90% confidence level. The mean of the heart rate changes to the intense patterns was shown in Figure 3-36. At 80% confidence level, the interval of the mean of the heart rate changes is less than zero in almost all the time windows except the third time window. This shows that people's heart rate response to intense patterns was also a deceleration compared to the baseline heart rate, except for the response in the third time window.

Comparison of the heart rate deceleration between weak and intense patterns was conducted. The difference of twenty participants' heart rate changes between the weak and intense patterns are reported in Appendix A.27. At 80% confidence level, significant differences were found in the 4th, 5th and 9th time windows as shown in Figure 3-37. The intervals of the mean of the difference on these time windows are less than zero. This shows that people's heart rate deceleration was higher to the weak patterns than the intense patterns in these time windows. However, the different heart rate change is only found in three discontinuous time windows, which is not significant for drawing the conclusion of people's different emotional response to the weak and intense patterns.

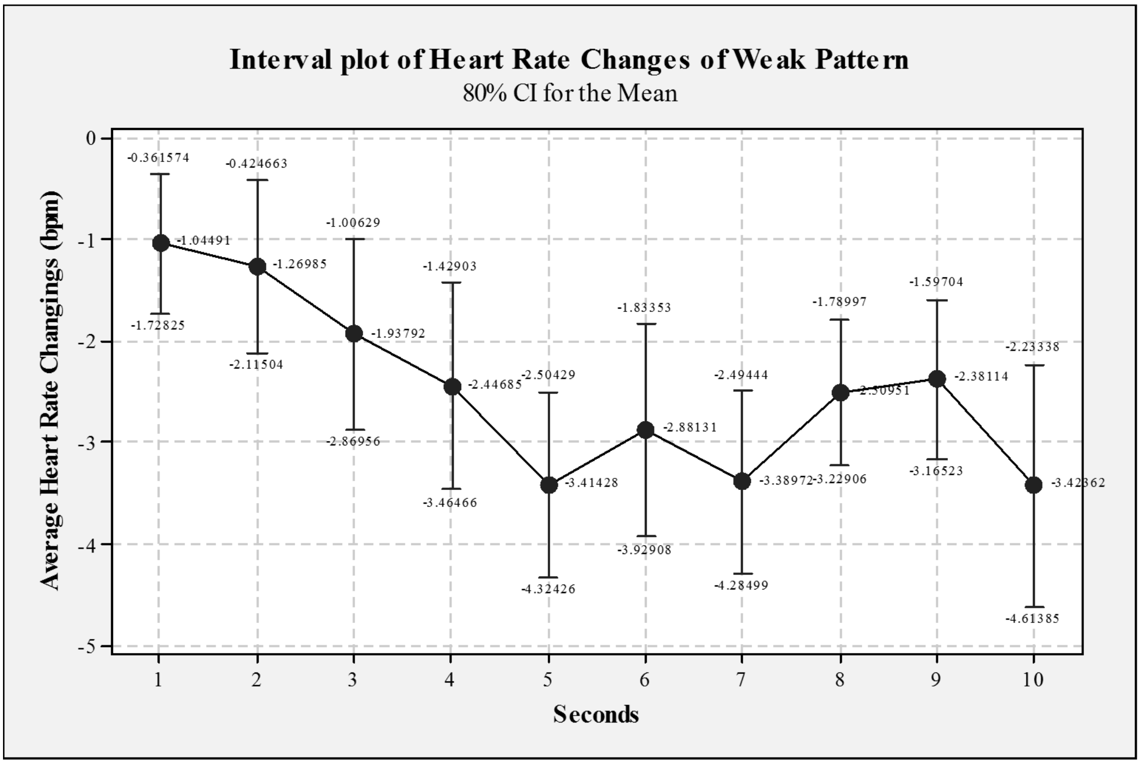


Figure 3-35 People's heart rate changes responding to the viewing of weak patterns.

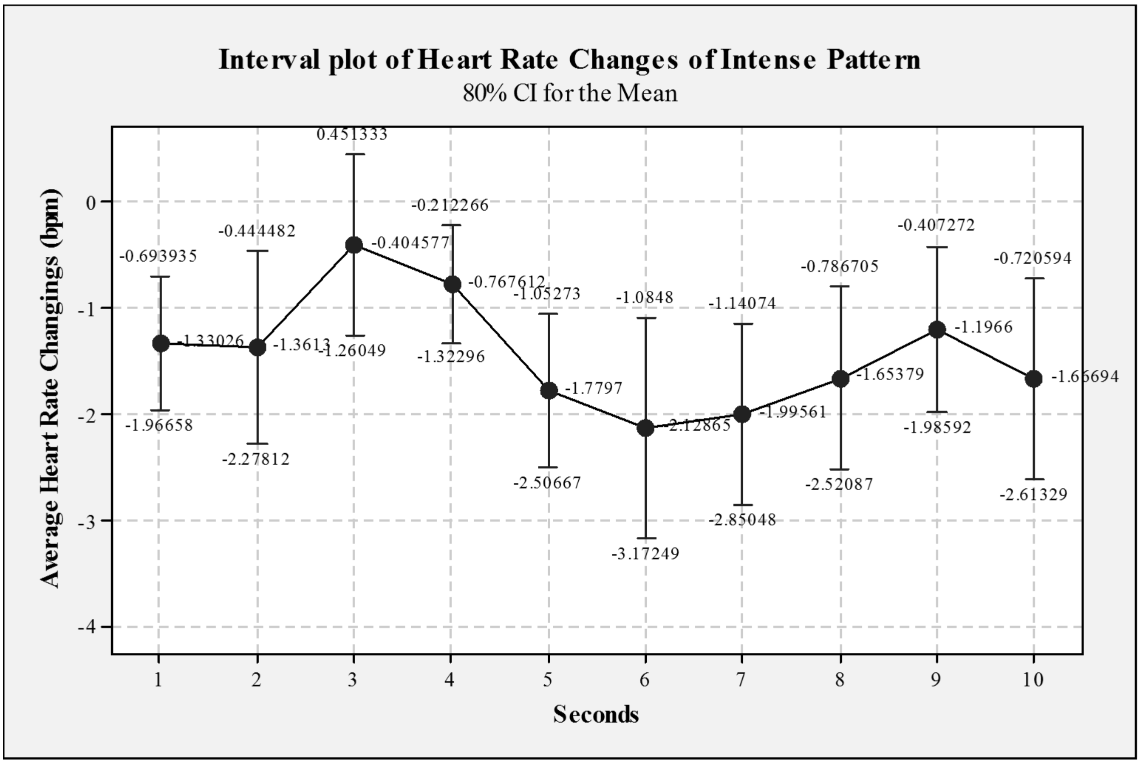


Figure 3-36 People's heart rate changes responding to the viewing of intense patterns.

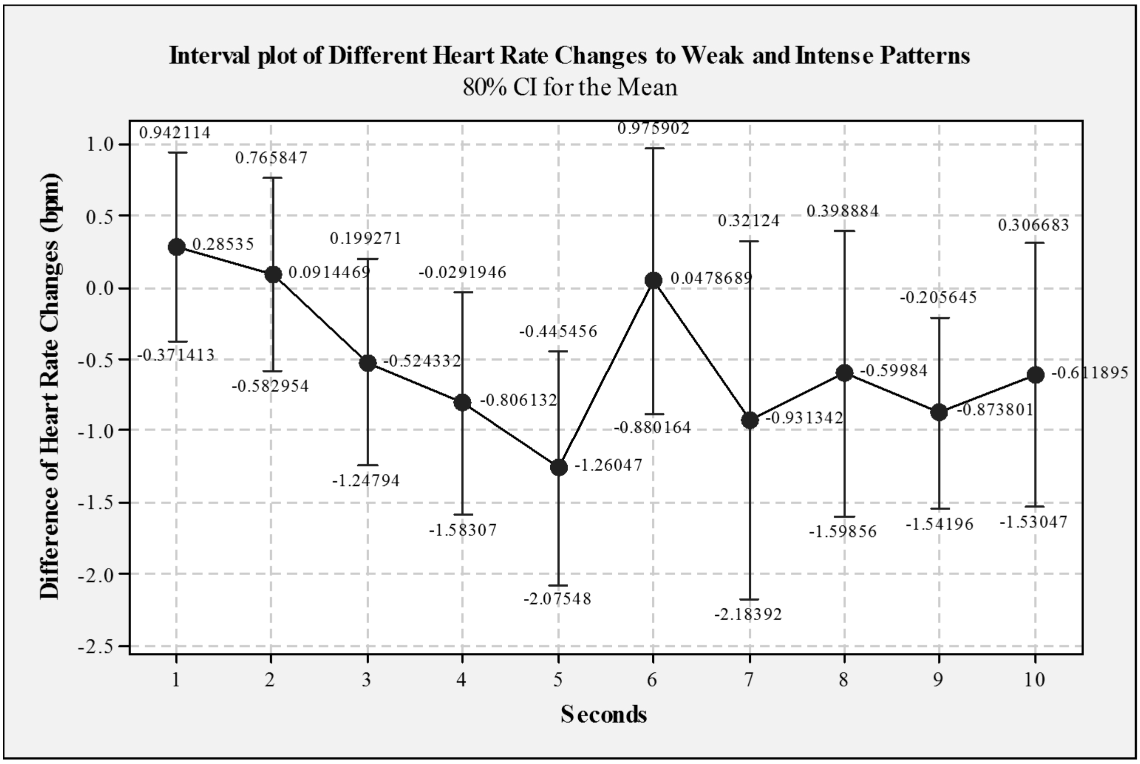


Figure 3-37 The differences of people's heart rate changes when viewing weak and intense patterns.

3.4.3.4 Subjective analysis

The averaging rating scores by the twenty participants of the Valence, Arousal, and Likert scales to the weak and intense patterns are reported in Appendices A.28 – A.30. One participant's rating scores on the three scales was removed because it was found unsuitably biased. The mean of the rating score of every scale was calculated by confidence interval estimation at 95% and the results are presented in Figure 3-38. In the Valence scale a significant result was observed in the intense patterns. The confidence interval estimation of the mean of the rating score shows the following:

Mean = 0.717,

Standard Deviation = 0.762,

Standard Error of the Mean = 0.175,

Confidence interval between 0.350 and 1.085.

The interval of the mean of the rating score to the intense patterns is over zero, which shows that the intense patterns were rated to have a pleasant positive effect. In the case of weak patterns, the mean of the rating score is undefined, either positive or negative, and therefore it has no significance, revealing no population valence response in the weak patterns.

On the Arousal scale, a significant result was found on the rating score of the intense patterns. The confidence interval estimation of the mean of the rating score shows the following:

Mean = 1.007,

Standard Deviation = 0.830,

Standard Error of the Mean = 0.190,

Confidence interval between 0.607 and 1.406.

The interval of the mean of the rating score is over zero, which shows that the intense patterns were rated to have an exciting effect. In the case of weak patterns, the mean of the rating score is undefined either positive or negative, and therefore it has no significance, revealing no population arousal response to the weak patterns.

On the Likert scale, a significant result was found on the rating scores of both weak and intense patterns. The confidence interval estimation of the mean of the rating score to the weak patterns shows the following:

Mean = 0.414,

Standard Deviation = 0.814,

Standard Error of the Mean = 0.187,

Confidence interval between 0.022 and 0.807.

The confidence interval estimation of the mean of the rating score to the intense patterns shows the following:

Mean = 0.776,

Standard Deviation = 0.887,

Standard Error of the Mean = 0.204,

Confidence interval between 0.349 and 1.204.

The intervals of the mean of the rating score to the weak and intense patterns are over zero, which shows that the weak as well as the intense patterns were both rated to have a positive result on people's preference.

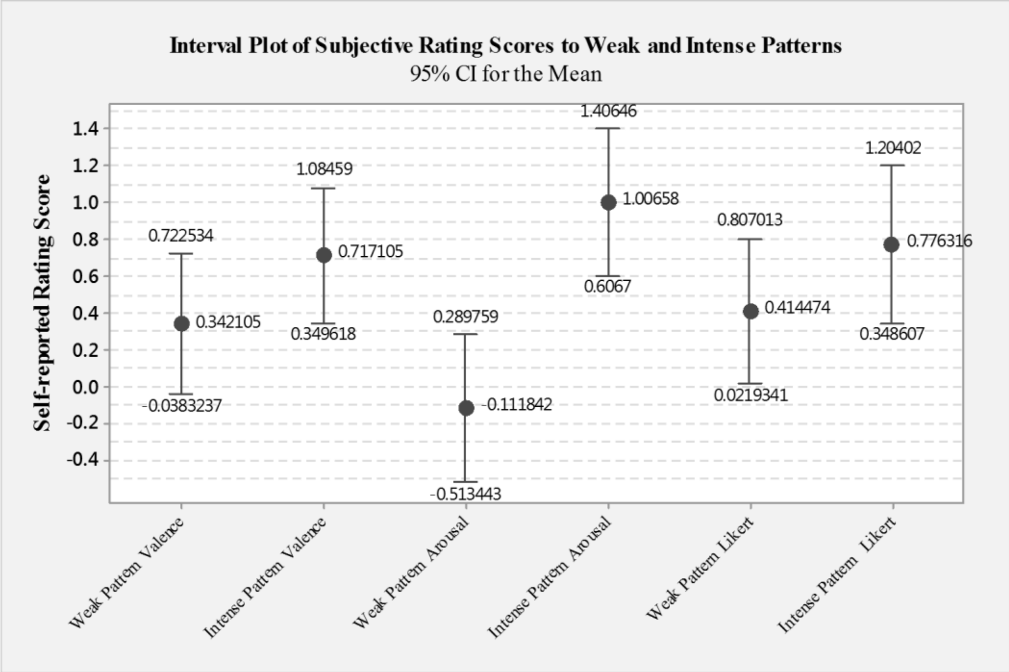


Figure 3-38 People's subjective rating scores when viewing to weak and intense patterns.

The significant differences of the rating scores between the weak and intense patterns were calculated on all rating scales and the results are shown in Figure 3-39. At 90% confidence level the significant difference was found in the Arousal scale. The confidence interval estimation of the mean of the difference shows the following:

Mean = -1.118,

Standard Deviation = 1.109,

Standard Error of the Mean = 0.254,

Confidence interval between -1.560 and -0.667, T=-4.40 and p-value=0.000.

The interval of the mean of the difference is less than zero, which shows that the intense patterns were rated as being more exciting. The mean of the difference on the Valence and Likert scale are undefined, neither positive nor negative, revealing no different arousal response or preference in people's response between the weak and intense patterns.

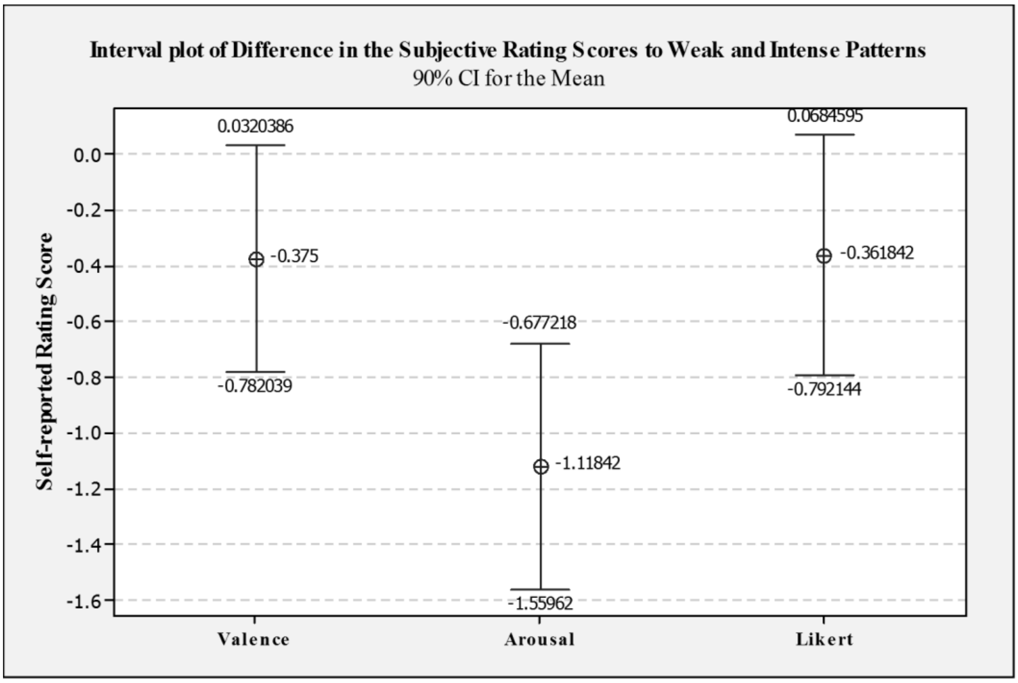


Figure 3-39 The difference in the subjective rating scores when viewing weak and intense patterns.

3.4.3.5 Result interpretation summary

A In the investigation of people's responses to weak and intense patterns, significant difference was observed in the Theta power response of the brain waves. The intense patterns evoked significantly higher Theta power over the parietal and occipital lobes of the brain compared to the weak patterns at 95% confidence level. The Theta power response of the brain has been found to be associated to human sensory and cognitive activities. The increasing Theta power in the posterior area of the brain, where the parietal and occipital lobes locate, has been found to be triggered by affective emotional stimuli compared with neutral stimuli [157] and has also been found in response to higher arousal stimuli in comparison with lower arousal stimuli [158, 159, 160]. Therefore, the current observation shows that the intense patterns have higher arousal emotional effect than the weak patterns. This result has an agreement with the finding in people's subjective evaluation. The intense patterns had a positive rating score on the Arousal scale at 95% confidence level, which shows that the intense patterns were rated to have an exciting effect on people's emotional response. Also, the result of the comparison between the weak and intense patterns shows that the intense patterns are rated as more exciting than the weak patterns at 90% confidence level with p-value at 0.000. Therefore, the results of the brain wave measurement and subjective evaluation suggest that intense patterns evoke higher excitement in viewers' response compared with weak patterns.

The results of people's subjective evaluation show that the intense patterns have a significant result on the Valence scale. At 95% confidence level, the mean of the rating score is over zero, which shows that the intense patterns were rated to have a pleasant effect on people's emotional response. The weak patterns have no significant rating score on the Valence scale, however, at 90% confidence level no significant difference was found in the pleasant effect between the weak and intense patterns. In the measurement of the Frontal Alpha Asymmetry index, the weak patterns have a positive index value at 90% confidence level, which shows that viewers have positive and approach-related emotional experience when responding to the weak patterns. However, no significant index value was found in the intense patterns, which means that viewers may have either positive or negative emotional experience when viewing the pattern. According to the results of the brain wave measurement and the subjective evaluation, the difference of people's pleasant responses between the weak and intense patterns is inconclusive, therefore, further study is needed.

3.5 Summary of the Results and Conclusions

We have investigated the emotional responses of twenty participants to the viewing of 4 groups of patterns by measuring their brain waves, their heart rate and their subjective evaluations using the SAM and 9-point hedonic scales. The 4 pattern groups were carefully designed so that the two groups consist of 8 regularly repeating patterns and 8 non-repeating patterns, and the other 2 groups consist of 8 weak patterns and 8 intense patterns. All patterns were black and white to limit any influence of colour. The data from these measurements have been statistically analysed and the significant results are summarised in Figures 3-40 and 3-41.

Between repeating and non-repeating patterns, the most significant difference observed in the current experiment is that repeating patterns have significantly more pleasant effect than non-repeating patterns and evoke a positive approach related to emotional experience. The result is supported by the measurements of people's subjective evaluation, their brain waves and their cardiac reactions. Therefore, patterns that contain regularly repeating elements, symmetrical and continuous characteristics have a more pleasant effect and influence people in a positive emotional experience compared with patterns that contain irregularly repeating elements, asymmetrical and discontinuous characteristics. This is a significant finding affecting not only design but our living world as a whole. It provided evidence that the features of repeat, symmetry and continuity in a pattern have influence on our life experience, our emotions, feeling, our environment and well-being. Significant difference found between weak and intense patterns is that intense patterns have higher arousal effect than weak patterns. This result is established by analysing people's subjective evaluation and their brain wave activity. Therefore, the features of intensity and complexity in a pattern also have influence on our emotions, in which patterns that are high in contrast, bold and complex evoke a higher level of excitement in people's emotional response compared with patterns that are faint, light and simple.

Having established the effect of different pattern characteristics on human emotion, on the other hand, the rapid development of technical textiles enables researchers to explore new interaction between textiles and users, in which the colour, pattern and shape-changing abilities of SMART textiles are used to interact with users' psychological state. Can we develop a pattern-changing fabric that actively influences people's emotional response by switching its effective patterns? Based on the findings in the current chapter, this research carried on a further investigation, which is reported in the following chapters.

Pattern Type	Subjective Evaluation			Brain Wave Activity		Cardiac Activity
	SAM Scales		Likert Scale	Frequency Band Powers of the Brain Waves	Frontal Alpha Asymmetry Index	Heart Rating Changes
	Valence Scale (Pleasant – Unpleasant)	Arousal Scale (Exciting – Calm)				
Repeating patterns Vs Non-repeating patterns	Repeating patterns was rated as more pleasant than non-repeating patterns at 90% confidence level, p-value 0.075.	No significant difference was found.	No significant difference was found.	• Theta frequency power: Repeating patterns triggered significant higher Theta frequency power in the centre frontal lobe of the brain, which might infer that the repeating patterns trigger a more pleasant effect than non-repeating patterns in people's emotional response. • Gamma frequency power: Non-repeating patterns triggers significant higher Gamma power in the Occipital lobe of the brain, which might infer that the non-repeating patterns have an unpleasant effect on people's emotional response compared with the repeating patterns.	At 90% confidence level, the mean of the index value of the repeating patterns is over zero, which shows that people experience a positive approach-related emotion when responding to the repeating patterns. No significant result was found in the non-repeating patterns.	Significant difference was observed in the initial 4 seconds of heart rate changes at 80% confidence level, in which the non-repeating patterns triggers a larger heart rate deceleration compared to the repeating patterns. This result shows that the non-repeating patterns might have an unpleasant effect on people's response.

Figure 3-40 Summary of established significant differences in people's emotional responses to the viewing of repeating and non-repeating patterns.

Pattern Type	Subjective Evaluation			Brain Wave Activity		Cardiac Activity
	SAM Scales		Likert Scale	Frequency Band Powers of the Brain Waves	Frontal Alpha Asymmetry Index	Heart Rating Changes
	Valence Scale (Pleasant – Unpleasant)	Arousal Scale (Exciting – Calm)				
Weak patterns Vs Intense patterns	No significant difference was found.	Intense patterns were rated as more exciting than weak patterns at 90% confidence level, p-value 0.000.	No significant difference was found.	• Theta frequency power: Intense patterns triggered significantly higher Theta power in the partial and occipital regions of the brain, which might infer that the intense patterns have more emotional effect than the weak patterns.	At 90% confidence level, the mean of the index value of the weak patterns is over zero, which shows that people experience a positive approach-related emotion when responding to the weak patterns. No significant result was found in the intense patterns.	At 80% confidence level, the difference of heart change when viewing the weak and intense patterns was found in the 4^{th}, 5^{th} and 9^{th} second after the pattern onset. This shows that people's heart rate deceleration was higher to the weak patterns than the intense patterns in these time windows. However, the result is not significant for the inference of people's emotional response.

Figure 3-41 Summary of established significant differences in people's emotional responses to the viewing of the weak and intense patterns.

CHAPTER 4 DESIGN PATTERN-CHANGING FABRICS MADE OF ELECTROCHROMIC COMPOSITE YARN

This research applied the pattern effects of repeating/non-repeating and weak/intense on the designs of pattern-changing fabric, and then investigated the psychological influence of these pattern-changing effects of the real fabric. It began with producing a new SMART composite yarn that can efficiently change colour by changes of the electric current, and this composite yarn was then used in knitting and weaving of fabrics. A number of fabrics were developed, which can change their pattern from one form to another. Finally, a collection of pattern-changing fabric was carefully designed and produced, which contains pattern-changing effects of repeating/non-repeating and weak/intense patterns. The design and production of these SMART composite yarns and pattern-changing fabrics are reported in this chapter.

4.1 Interactive Pattern-changing Textiles

To generate interactive patterns, some SMART fabrics use light-emitting material such as light-emitting diode (LED) or electroluminescent (EL) lines; others use thermochromic dyes or pigments. The end result by the thermochromic materials is close to conventional textiles. Hence, in the current research, thermochromic dyes have been used to create the interactive effects. Most pattern-changing effects are produced by printing thermochromic pigments on fabrics. Thermochromic yarn is not yet available in the commercial market. It limits the creation of the pattern-changing effect on knitted fabrics, on which patterns are usually constructed by using different colour yarns. To overcome this shortage, this research developed a yarn that is suitable for colour changing effects and was subsequently used in fabrics designed specifically to test the emotional effects on viewers.

4.1.1 *Thermochromic colours*

In general, thermochromic dyes consist of three components contained in a microcapsule, which are: an acid activator, an organic dye and a low melting pointing solid solvent. The principle of thermochromism is that when the temperature is below the melting point of the solvent, the colour forming components are held in contact and interact with each other, therefore a visible colour occurs; when the temperature is above the melting point, the solvent is liquefied leading to the colour forming components being separated with no interaction, therefore no visible colour occurs [161]. Accordingly, a fabric printed with thermo-chromic colour can change from being coloured to colourless when its temperature is above the activation temperature of the thermo-chromic colour; and reverse back to being coloured when the temperature drops below the activation temperature. Thermochromic colours have been successfully used on textile products. For example, back in the early 1990's, Hypercolour was commercialised, which was a type of garment coloured by thermochromic dyes, capable of changing colour from dark to fading when heated or cooled. A similar product launched in 2008 by American Apparel was a jersey t-shirt that changes colours according to the wearer's body temperature. In footwear, a heat sensitive sneaker, designed by Puma, named Basket Colour Change, can also change colour when the wearer's foot temperature and the surrounding environment vary.

4.1.2 *Design and develop interactive pattern-changing textiles*

Thermo-chromic dyes offer fabrics a capability that can sense and react to the alteration of temperature. They have been applied to designing SMART textiles. For example, Orth produced an electronically activated textile display, named Electric Plaid shown in Figure 4-1. It is a woven fabric printed with different thermochromic colours and layers of patterns. The fabric also carries conductive yarn and electronic circuitry. When connected to a power supply, the Electric Plaid will change patterns gradually [162, p106-107]. Berzowaka with her team from Xslabs designed a collection of animated textiles, two examples being shown in Figure 4-2. One is named Krakow Weaving, which is a Jacquard woven fabric with figures appearing from black colour to transparent, as a result the people in the image disappear over time. The other example is Animated Quilt, which is a quilt fabric with 100 squares that can selectively change colour from black to white, so that it functions as a 100 plex display [163]. Worbin designed dynamic patterns on fabric by using thermochromic colours. One of her works is shown in Figure 4-3, named 'Being Square'. It is an apron and a tablecloth that are connected to each other through the patterns. The pattern on the apron can change between stripes and checks, while the tablecloth has a static pattern. When the pattern on the apron changes to checks, the apron matches the tablecloth [164]. Berzina's project named ‘System’ as shown in Figure 4-4 shows an idea of ‘living’ textile membranes which images slowly appear and disappear on its surface and create fleeting marks. She explains that conductive yarns, electronic control and thermochromic inks were used to create the periodic colour-changing effect [165]. Recently, textile designer Karpati created a sound interactive fabric named Chromosonic as shown in Figure 4-5. It produces shifting patterns when responding to sound. The patterns were screen-printed using thermochromic colours; conductive wires were woven into the fabric; a microcontroller and circuit boards were used to control the appearance of the pattern and the interaction with sound [166].

The given examples show designs of pattern-changing textiles with the application of thermochromism. These designs contain three essential parts; thermochromic pigments, electrical conductive materials and customised electronic components. They combine the electrical conductive materials with textile fabric through adhesive, stitching or weaving, in which electrically conductive yarn has been popularly used as the conductive material. The thermochromic pigments are then printed on the fabric to create patterns. When electric current goes through the conductive material; heat is generated and triggers the colour-changing phenomenon of the thermochromic pigments on the fabric, which causes a pattern-changing effect. The electric supply is able to be controlled through purpose-made electronic devices, therefore the pattern-changing effect can be designed and pre-programmed. The combination of thermochromic pigments, electrically conductive materials with textiles has been limited in fabric creation materials, therefore in this research, an electrochromic yarn is being explored, which is an electronic conductive yarn with thermochromic colour, and it has the capability to change colour by controlling its electric voltage. This yarn is also suitable for weaving and knitting. This new yarn developed in this research extends the ability of integration of thermochromic colour with textiles, for weaving and knitwear production.

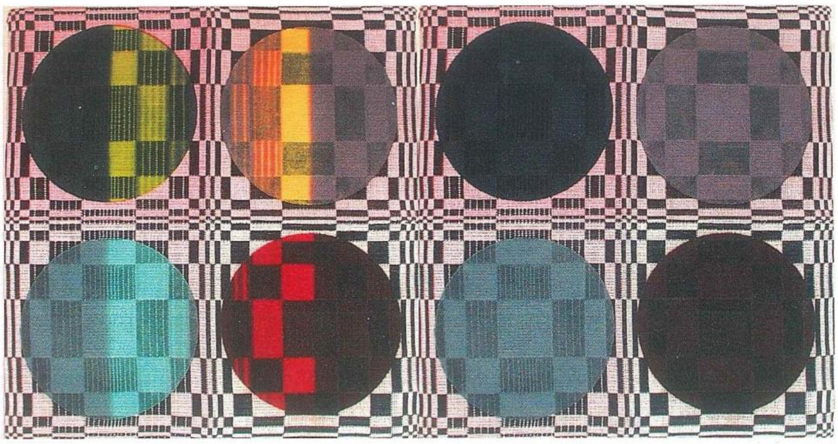
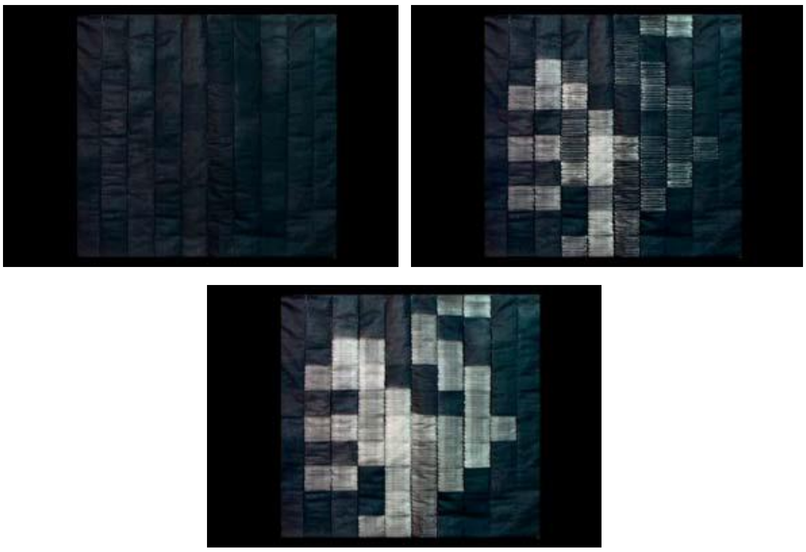


Figure 4-1 Electric Plaid [162, p107].

Krakow Weaving



Animated Quilt [167]

Figure 4-2 Animated Textiles [163].

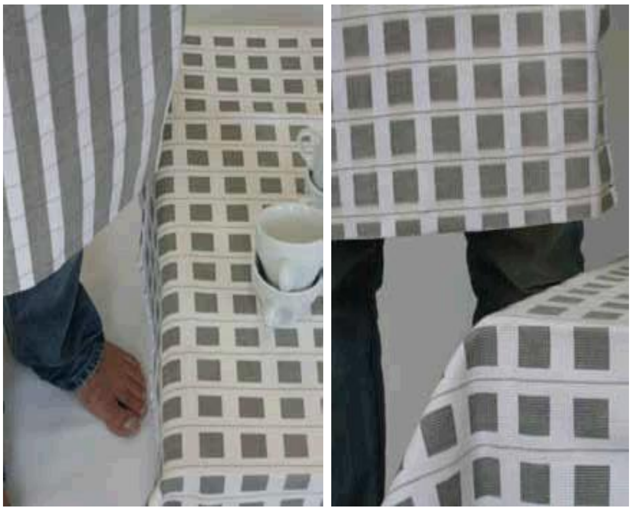


Figure 4-3 Being Square [164].

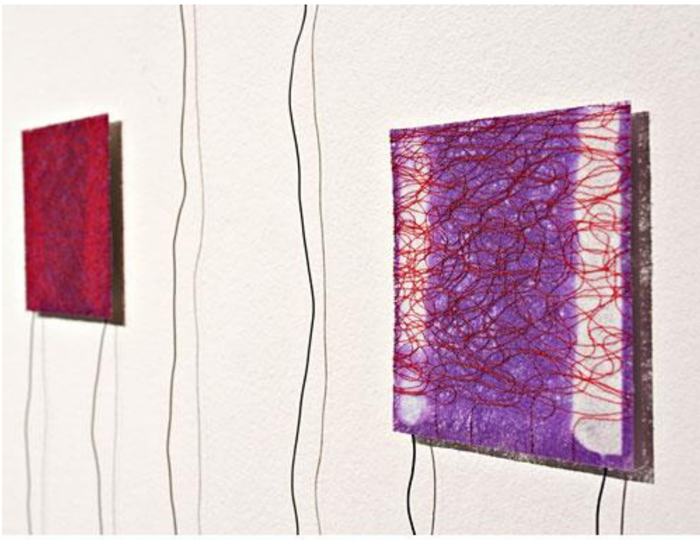


Figure 4-4 The System [165].

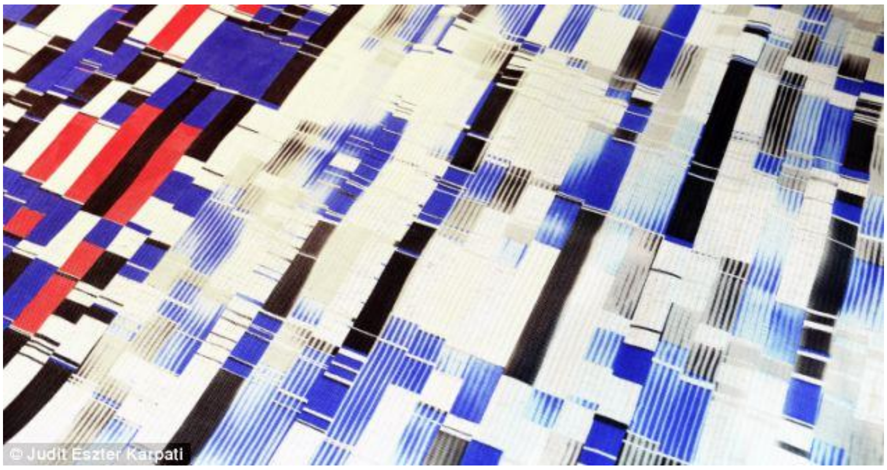


Figure 4-5 Chromosonic [166].

4.2 Design of a SMART Electrochromic Yarn

The conceptual model of a SMART yarn is presented in Figure 4-6. It is a yarn that has an electronically controlled colour-changing effect. The core section of the yarn is an electrically-conductive material with resistance heating properties. It is able to convert electricity into heat. The surface of the yarn has a layer of thermo-chromic colour. When an electric current passes through the yarn, heat is produced from its core section and triggers the colour-changing effect on its thermo-chromic surface. When the electric current is stopped, the heat inside the core section dissipates, its temperature drops, and causes the thermo-chromic surface recover to its original colour. Therefore, the SMART yarn can change colour by electric current selection on and off.

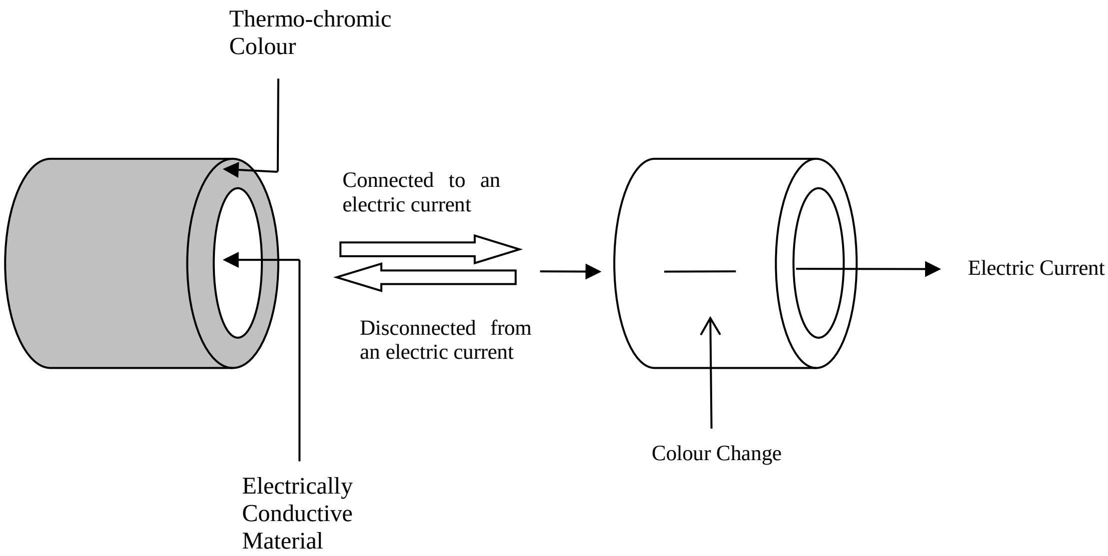


Figure 4-6 The conceptual model of the SMART colour-changing electrochromic yarn.

4.3 Yarn Specification Requirements

The material for the core section of the SMART yarn is critical. It has to be electrically conductive, able to convert electric current to heat and also suitable for textiles production. Copper wire was chosen in this research, because copper is an excellent conductor of both electricity and heat, and it also has good electrical resistance properties. The copper wire with low thickness is very soft and flexible, for example, the tinned copper wires with a diameter of 0.05mm, 0.08mm and 0.10mm. Hence, they have good properties for blending with yarns without adding greater rigidity. However, copper wire with a very small-gauge of thickness also has very low strength. During preliminary experiments, the three types of copper wire mentioned were not able to withstand the extension and bending generated from the weaving or knitting processes.

A normal textile yarn has to be blended with the thin copper wire which increased the strength and pliability during the fabric production.

4.4 The SMART Yarn Spinning

The composite of copper wire and a normal textile yarn was produced through commercial yarn spinning machinery using a Gemmill and Dunsmore hollow spindle fancy yarn machine. In Figure 4-7, it shows a schematic diagram representation of the process of yarn spinning and blending of the machine.

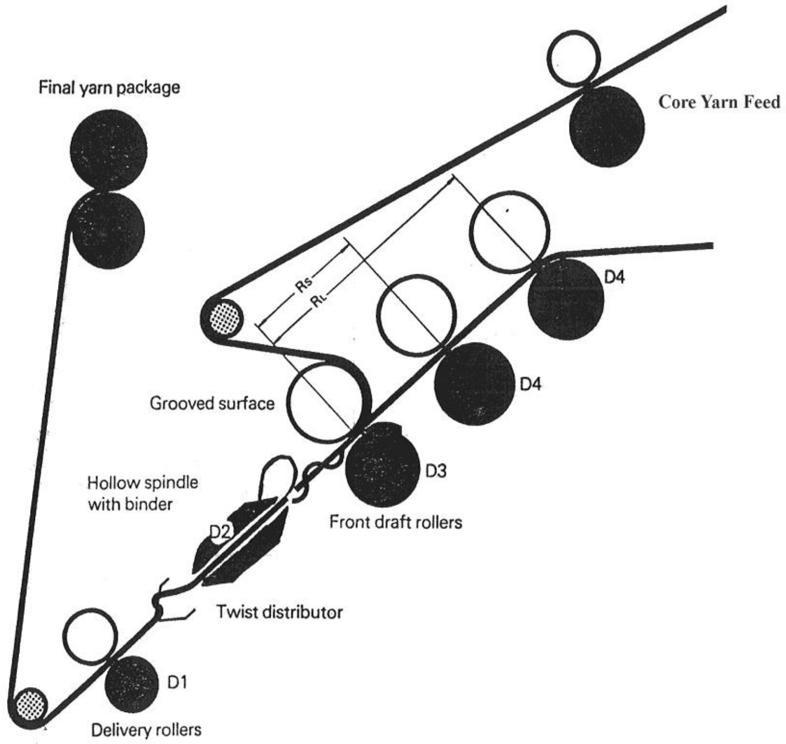


Figure 4-7 A schematic diagram of the SMART yarn spinning process in the Gemmill and Dunsmore machine.

During the spinning process, a copper wire and a textile yarn were set parallel to each other and fed into the rollers as a core yarn material; they passed through the centre of the feeding rollers into the front draft rollers D3; and then run through the hollow spindle D2, where they were wrapped by a binding yarn. The composite yarn was finally produced by the delivery rollers D1 and wound up on the final yarn package. In Figure 4-8, there are three images taken during the spinning process. The image on the left shows a special stand designed for delivering the copper wire into the machine; the image in the middle shows the hollow spindle D2 and the final yarn package; and the image on the right is the control panel of the machine. The diagrammatic representation of the display screen of the control panel is shown in Figure 4-9. The speed setting of the rollers is critical during the spinning process, because it controls the quality of the yarn as well as its structure. And the speed setting on the hollow spindle D2 determines the number of wraps that the binding yarn makes around the core yarn, in units per metre. Since the mechanical behaviour of the copper wire is different from that of the normal textile yarn, many experiments had to be conducted to obtain the optimum roller settings for spinning. Care had to be taken when adjusting the speed setting of the rollers and the hollow spindle to avoid the introduction of faults into the composite yarn, such as breaks of the copper wire or loose loops of the wire. During these experiments, three types of copper wire mentioned in section 3.2 were tested for spinnability. The tinned copper wires with diameter of 0.05mm and 0.08mm couldn't withstand the tension generated during the spinning process, and produced many breakages. The last one of the copper wires with diameter of 0.10mm in silver colour performed well. It was found that the optimum speed settings on the machine are 20 metres per minute in rollers D3 and D1, which minimises excessive tension and twisting on the copper wire, and 4000 wraps per minute in the hollow spindle D2, which represents the binding yarn in the hollow spindle gives the core yarn 200 wraps per metre.

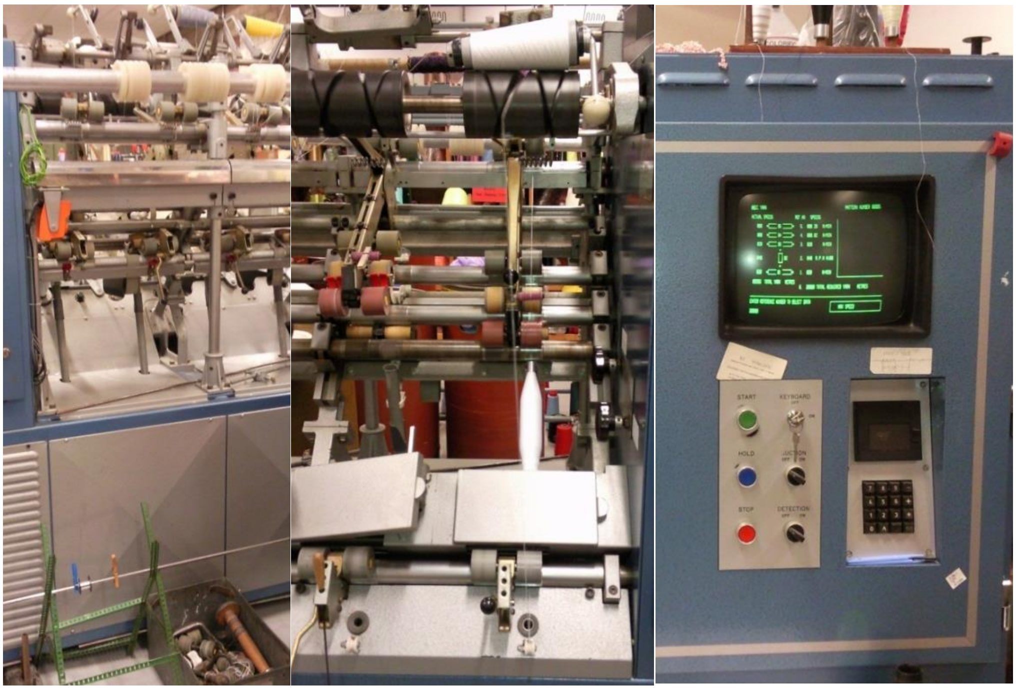


Figure 4-8 Three images of the SMART yarn spinning on the Gemmill and Dunsmore machine.

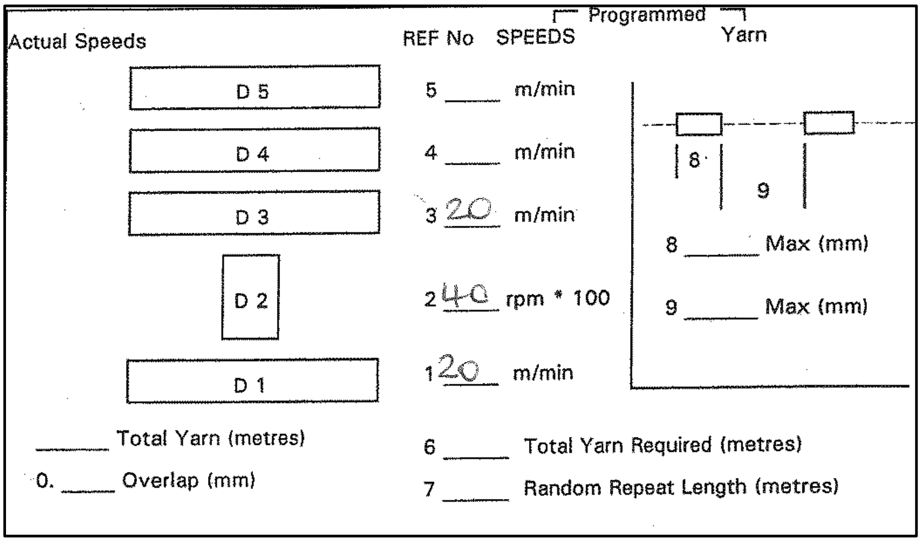


Figure 4-9 The diagram representation of the display screen of the the Gemmill and Dunsmore machine.

Investigation continued using the silver coloured copper wire with four different types of yarn, producing four types of SMART composite yarn, A, B, C and D as shown in Figure 4-10. The four yarns are 180 Tex fine wool in creamy colour, 30 Tex silk in light green colour, 58 Tex spun viscose in white colour and 20 Tex cotton in white colour. All SMART composite yarns were spun with the optimum machine settings established and the same binding yarn, which is a ply of 16.1 Tex polyester filament in white colour. These SMART yarns have different colours, thicknesses and handle, which are generated by the properties of their blended yarns. The copper wire adds a metallic effect and a slightly rigid handle to the SMART yarns.

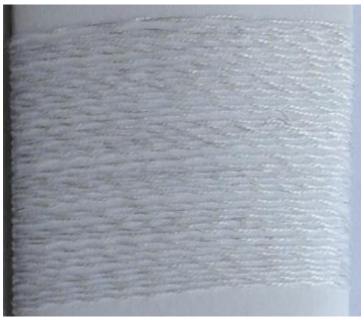
<table>
<tr><th rowspan="2">Yarn Code</th><th colspan="2">Core Yarn</th><th rowspan="2">Binding Yarn</th><th rowspan="2">Composite Yarn Sample</th></tr>
<tr><th>Textile Yarn</th><th>Copper Wire</th></tr>
<tr><td>A</td><td>180 Tex Superfine Wool
in Cream</td><td rowspan="4">Silver-plated Copper Wire (diameter 0.10mm)</td><td rowspan="4">16.1 Tex White Polyester Filament</td><td></td></tr>
<tr><td>B</td><td>30 Tex Silk
in Light Green</td><td></td></tr>
<tr><td>C</td><td>58 Tex Spun Viscose
in White</td><td></td></tr>
<tr><td>D</td><td>20 Tex Cotton
in White</td><td></td></tr>
</table>

Figure 4-10 Four samples of the SMART composite yarn.

A 35 times magnified image of SMART composite yarn D is shown in Figure 4-11. It shows that the copper wire and the cotton yarn are blended together, and the binding yarn is almost invisible inside the core of the yarn.

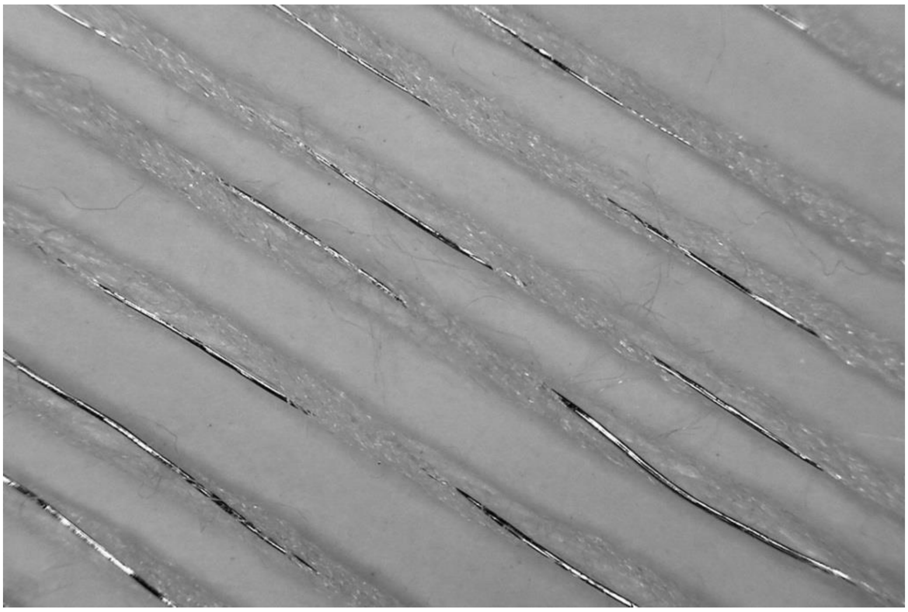


Figure 4-11 A 35 times magnified image of the SMART composite yarn (sample D).

4.5 Investigating the Colouration of the SMART Yarns

4.5.1 *Thermo-chromic colour pigment*

The SMART yarn surface is designed as a layer of thermo-chromic colour. Since the SMART yarn contains not only the ordinary textile material but also a copper wire, a special thermo-chromic pigment was investigated (Chromazons' Water Based Sprayable system 1510 supplied by the LCR Hallcrest Ltd). The pigment is suitable for using with metal surfaces. The system consists of three parts: a clear lacquer, a thermo-chromic pigment and an adhesion promoter. The thermo-chromic pigment is black in colour and has an activation temperature of 31^{o}C. This means that the colour pigment stays black when its temperature is less than 31^{o}C and changes to colourless when the temperature reaches 31^{o}C or over. Although this pigment is made for metal and ceramic purposes, it was successfully applied to textile yarns for the first time.

4.5.2 *Colouration tools*

To apply the Chromazons' Sprayable system, an airbrush was used, (Model 200 Airbrush from the Badger Air-brush Company), with an air compressor for supplying the compressed air to the airbrush, shown in Figure 4-12.

Figure 4-12 The airbrush and the air compressor used for colouring the SMART yarn.

4.5.3 *The colouration process of the SMART yarn*

The first step of this process is the preparation of the thermo-chromic colour system, which was made up of 55.9% clear lacquer, 24% thermo-chromic pigment, 1.1% adhesion promoter and 19.0% water by optimising the process specification from the supplier. The solution was mixed in a mechanical stirrer. Secondly, the SMART yarn was wound onto a wooden frame which had nails in opposite sides and which were parallel to each other, the yarn was wound around the nails. Thirdly, the prepared solution was filled into the glass jar of the airbrush and evenly sprayed over the SMART yarn. Spraying was repeated several times until the whole yarn was covered with black colour. Then, the yarn as was set in the wooden frame was placed in a pre-heated oven at 100^{o}C for 5 minutes, for curing the thermo-chromic pigment. After being taken out of the oven, the coloured SMART yarn was left to cool down to room temperature, and then wound onto a yarn cone. Figure 4-13 shows two images of the SMART yarn on the wooden frame before and after colouration.

Before coloration

After coloration

Figure 4-13 The images of the SMART yarn before and after colouration.

In Figure 4-14, a 35 times magnified image of the coloured SMART yarn sample D is shown. The surface of the yarn is almost covered in dark grey to black colour. In some areas, the copper wire isn't coloured by the pigment, exposing its silver surface.

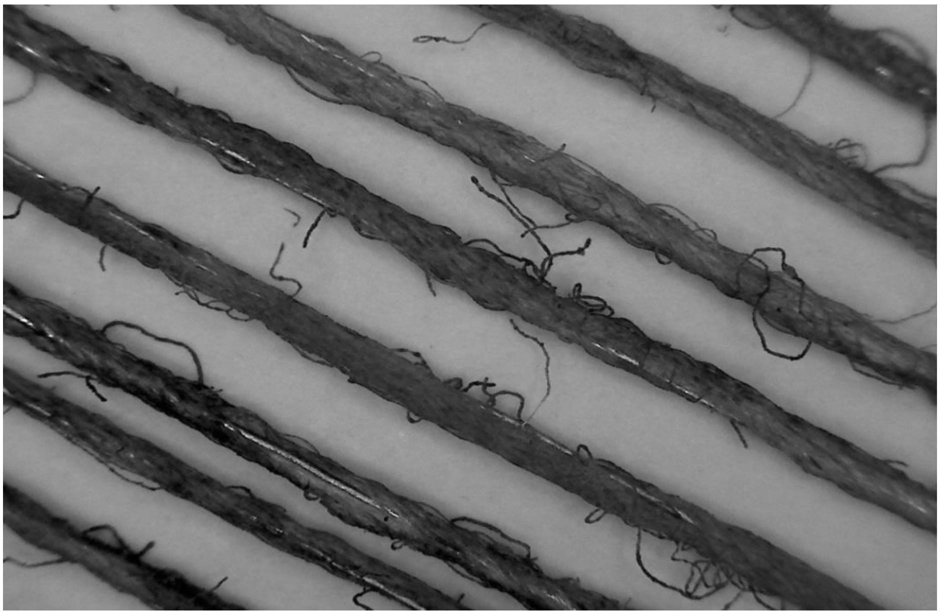


Figure 4-14 A 35 times magnification image of the coloured SMART yarn (sample D).

4.5.4 *The electronically-controlled colour-changing effect of the SMART yarn*

The coloured SMART composite yarn was further investigated for its colour-changing effect. Since its electric conductivity comes from the copper wire and the colour-changing effect from its thermo-chromic surface, when an electric current is applied across it, heat is produced from the copper wire which triggers the thermo-chromic surface to change colour from black to colourless, i.e., as the yarn was before coloration. When the current supply is off, the heat inside the copper wire dissipates, the temperature of the yarn drops, and the thermo-chromic surface reverses back to the black colour, i.e., the yarn has two states, a coloured state and a colourless, being selectable by applying an electric current across the yarn.

For an example, SMART yarn sample D is shown in Figure 4-15. The yarn sample was uniformly wrapped around the edges of a white cardboard. Its total length is 4 metres. In a room temperature environment of 20^{o}C and 75% relative humidity, the sample was in black colour and its electrical resistance was 9 ohms. When a 3 volts electric supply was applied across it, the sample changed its colour from black to light grey, and then to almost white in a time period of 40 seconds. After removing the supplied current, the yarn gradually changes from white colour to black colour in around 40 seconds.

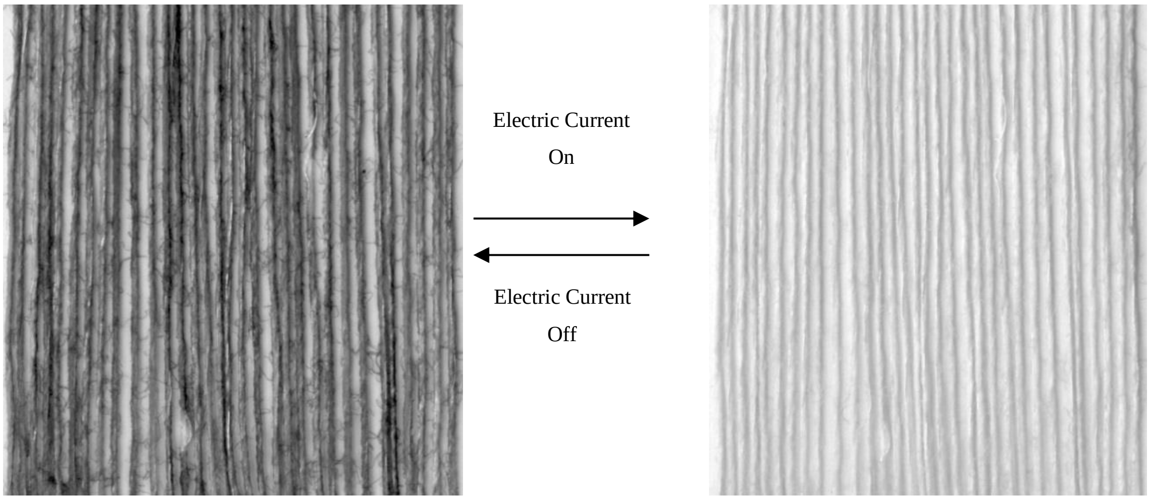


Figure 4-15 Electronically-controlled colour-changing effect of the SMART yarn.

It was found that the optimum electric current supplied to the samples of the SMART yarn for triggering the colour changing effect was between 0.3A to 0.4A. When the electric current is too high, the SMART yarn is burned up; when the electric current is too low, the colour changing effect is not activated. It is seen that the coloured SMART composite yarn has fulfilled the aims described in section 4.2. In the following section, the SMART composite yarn is used as a key material for developing pattern changing.

4.6 Design and Development of Pattern-changing Fabric

The pattern-changing effect in the current research is an effect that enables the material to change appearance may be but not exclusively by controlling the supply of electric current. A number of fabric samples were designed and made by both knitting and weaving processes. Four knitted samples and two woven samples were investigated. With electronic control, samples can reveal and conceal their patterns, vanish or change their pattern from one form into the other.

4.6.1 *Knitted pattern-changing fabrics*

Fabric sample 1 was produced on a standard gauge manual knitting machine shown in Figure 4-16. The pattern was produced by a punch card system, which can control the needle engagement and disengagement following a pre-designed pattern on the punch card. The punch card used for fabric sample 1 is shown in Appendix B.1. It requires two different yarn colours to create the pattern, one for the pattern and the other as background. In sample 1, the coloured SMART yarn A was used on the pattern; and the creamy superfine wool that was spun as a core of the SMART yarn A was used as background. The finished pattern was 10.5cm in width and 12cm in height, and its resistance was 30.2 ohms. At room temperature of 20^{o}C and 75% relative humidity, when the fabric was supplied with a 12 volts electric potential, the pattern started to fade out from the centre and spread to the edges, it finally completely disappeared in 60 seconds. After turning the current supply off, the pattern emerged again, starting from the edges then back towards the centre, and was completely restored in about 2 minutes. Four images in Figure 4-17 show the pattern-changing effect of fabric sample 1.

Figure 4-16 Knitted fabric sample 1.

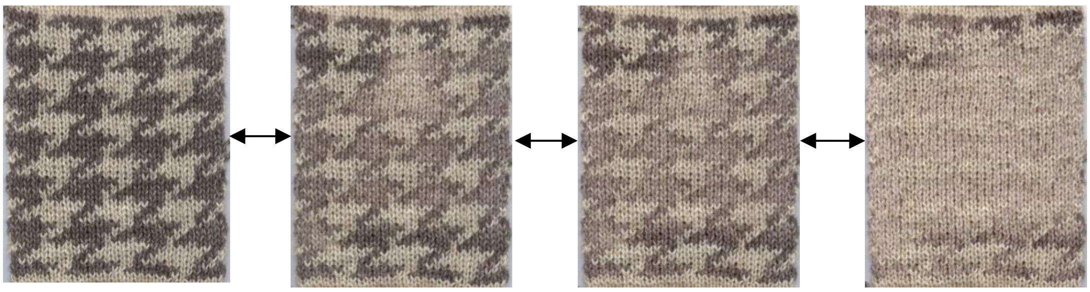


Figure 4-17 Pattern-changing effect of knitted fabric sample 1.

Fabric sample 2 is shown in Figure 4-18. It was made on a fine gauge manual knitting machine. As before, its pattern was also produced by a pre-designed punch card, which is shown in Appendix B.2. In this sample, the coloured SMART yarn B was used on the pattern and the light green silk that was spun as a core of the SMART yarn B as the background of the fabric. The size of the pattern was 10.5cm in width and 10cm in height, and its resistance was 21.3 ohms. At a room temperature of 20^{o}C and 75% relative humidity, as soon as 9 volts electric potential was applied across the fabric, the pattern immediately starts to fade and it completely vanished in about 90 seconds. When the electric power was deselected, the pattern appeared again in about two minutes. This pattern-changing effect is shown in the images of Figure 4-19.

Figure 4-18 Knitted fabric sample 2.

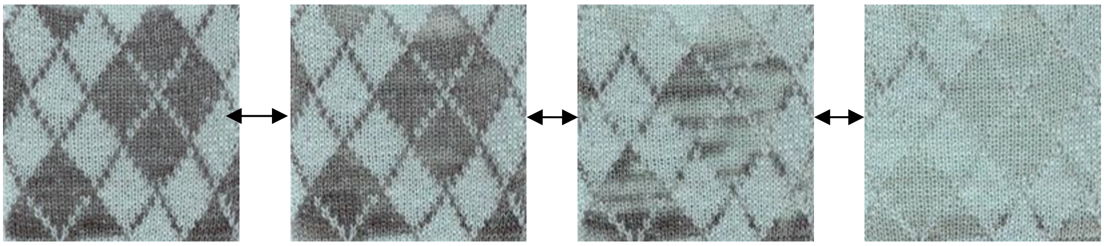


Figure 4-19 Pattern-changing effect of knitted fabric sample 2.

As can be seen, the first two samples have the same type of changing effect, which is a pattern vanishing and re-appearing. The principle of creating this effect is because the SMART yarn is used in the pattern, and a normal yarn is used in the background; the normal yarn has a similar colour and physical appearances to the SMART yarn after its colour change. Therefore, when applying the electric current, the SMART yarn changes its colour and its pattern becomes the same colour as the background colour, thus creating the effect of blending into the background and vanishing; when the supply is off, the SMART yarn reverses back to its original colour, distinctly from its background, hence its pattern stands out and re-appears.

Another knitted fabric, sample 3, was designed with a different effect, shown in Figure 4-20. It was produced on an eight-gauge Shima Seiki SES 122 S electronic knitting machine. The Shima Seiki machine is popular in the knitting industry and it can be controlled by computer design software to create more diverse structures and patterns, which are not possible on a manual machine. The structure of sample 3 is a three-colour bird's eye jacquard. The pattern was pre-designed on computer CAD software and was then sent to the knitting machine. The design program of this fabric is reported in Appendix B.3. Several tests had been conducted before fabric production, to attain suitable tension and production speeds, which are critical to maintain the functions of the SMART yarn without any damage and to promote the quality of the fabric pattern. The optimal speed setting on the machine is 0.5 metres per second, which is slightly lower than the commercial production speed. The tension setting of the stitch motor is 28, representing a stitch length of approximately 8.7 mm. This fabric sample was knitted with the coloured SMART yarn sample D, 100 Tex cotton yarn in grey colour and 112 Tex cotton yarn in black colour. The finished pattern had 20.5 cm width and 13cm height, and its resistance was 45 ohms. At a room temperature of 20^{o}C and 75% relative humidity, when a 12 volts electric supply was applied across the sample, the fabric changed its pattern from a two-dimensional effect to a three-dimensional effect, as seen as in Figure 4-21, in about 2 minutes. When the current was off, its three-dimensional pattern slowly changed back to the two-dimensional effect in about 4 minutes.

This changing effect alters a pattern from one form to the other. To create such a transforming effect, the pattern is created by three different yarns, the SMART yarn, one normal yarn that has a similar colour and physical appearance to the SMART yarn, and another normal yarn in a different colour. Therefore, the pattern looks like having two colour sections before transforming; when the SMART yarn changes its colour, the pattern generates three colour sections, leading to a different and interesting structure and appearance.

Figure 4-20 Knitted fabric sample 3 produced on an eight-gauge Shima Seiki SES 122 S knitting machine.

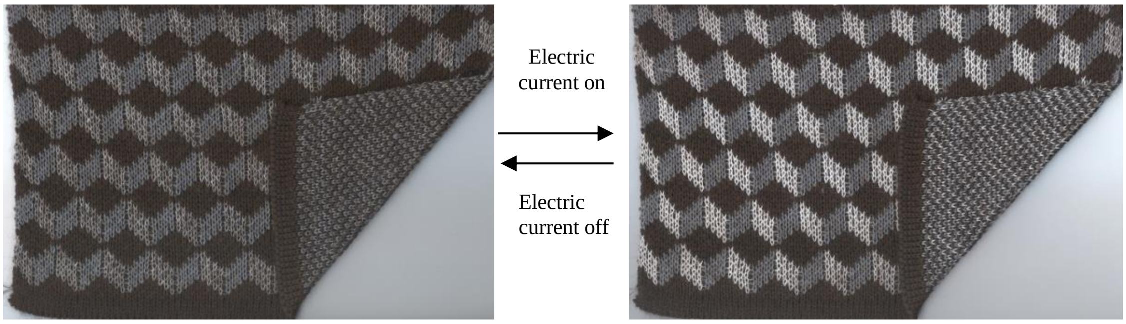


Figure 4-21 The pattern-changing effect of knitted fabric sample 3.

4.6.2 *Woven pattern-changing fabrics*

Two more fabrics were designed and made by the weaving process. A double weave structure was used for the pattern-changing fabric, which has two layers that are woven on two sets of warp yarns (face and back) and connected by a weft yarn moving between the two layers. Choosing a double weave structure is because the SMART yarn could be woven into the face warp where a colour-changing effect is required and woven into the back warp where the colour-changing effect needs to be concealed. Two woven samples were produced on a manual Dobby floor loom, and from the same warp which is composed by a black cotton yarn of 2/19 yarn count and a white viscose yarn of 2/20 yarn count. The pattern on the fabrics was created by using different shaft lifting plans and weft insertion plans. The information on the weaving design of these samples is presented in Appendices B.4 and B.5.

The first woven sample 1 is shown in Figure 4-22. It used three different weft yarns: the coloured SMART yarn sample C, a cotton yarn of 2/19 yarn count in back colour and a viscose yarn of 2/20 yarn count in white colour. The design had a three colour checked pattern (black, grey and white). The size of the pattern was 17.5 cm in width and 14 cm in height and its resistance was 14.3 ohms. At a room temperature of 20^{o}C and 75% relative humidity, when a 6 volt electric potential applied across the fabric, the pattern changed to a two colour checked pattern (black and white) as shown in Figure 4-23. The change took about 20 seconds to complete, and upon stopping the supply, the pattern recovered to its original three colour checked pattern in about 60 seconds.

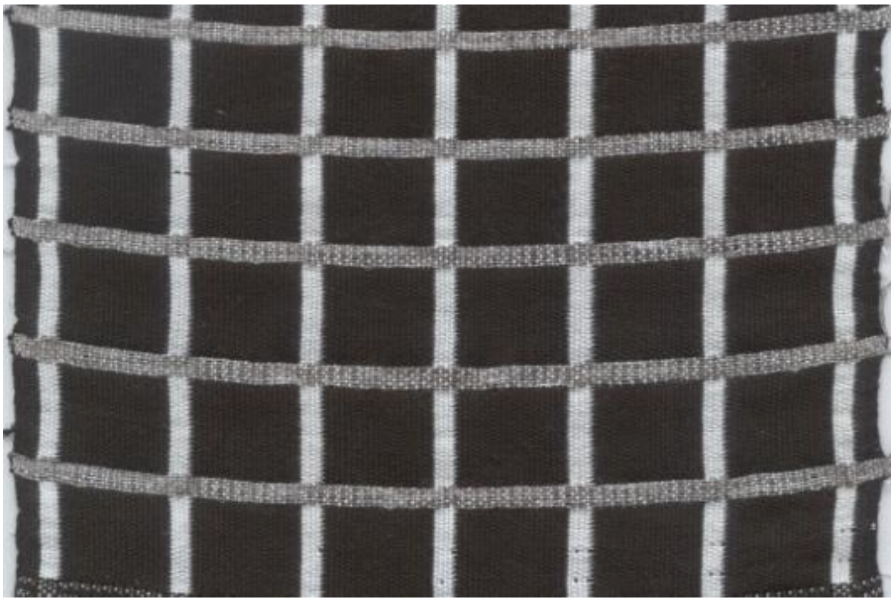


Figure 4-22 Woven fabric sample 1 produced on a manual Dobby floor loom.

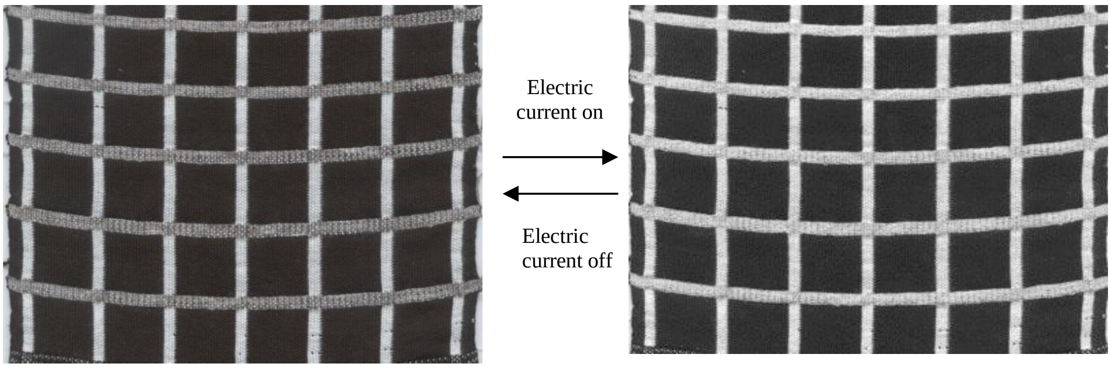


Figure 4-23 The pattern-changing effect of the woven fabric sample 1.

The second woven sample 2 is shown in Figure 4-24. It had a similar geometrical pattern design as the first sample. The sample used four different weft yarns, including the coloured SMART yarn sample C, a cotton yarn of 2/19 yarn count in black colour, another cotton yarn of 2/19 yarn count in grey colour and a viscose yarn of 2/20 yarn count in white colour. The size of the pattern was 18cm in width and 17cm in height, and its resistance was 18 ohms. In a room temperature of $20^{o}C$ and 75% relative humidity, when subjected to a 7.5 volts electric supply, the horizontal lines of the pattern changed colour from dark grey to light grey, causing a different appearance of the pattern as shown in Figure 4-25. This changing effect is completed in about 30 seconds and upon stopping the supply, the pattern recovered to its original form in about 60 seconds.

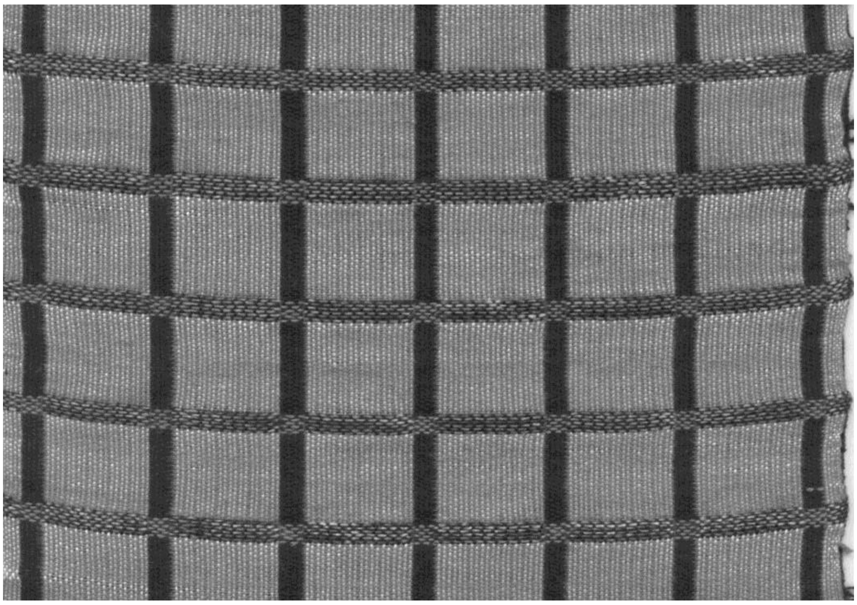


Figure 4-24 The woven fabric sample 2 produced on a manual Dobby floor loom.

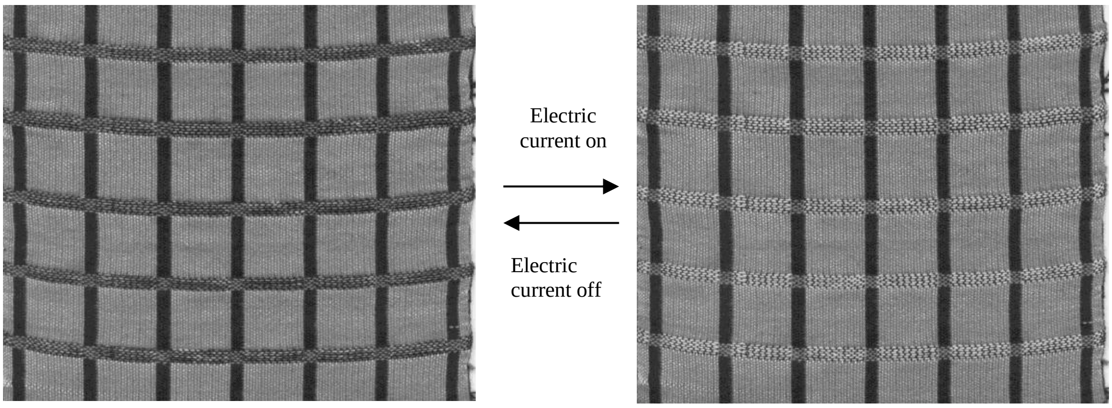


Figure 4-25 The pattern-changing effect of the woven fabric sample 2

The principle of the pattern-changing effect of the woven samples is also based on the colour changes of the SMART yarn, which changes the colour sections of the pattern, therefore, producing a different and dynamic appearance in the pattern. This effect was made possible using one normal yarn in the pattern that has a similar colour and physical appearances to the SMART yarn either before or after the colour change.

4.7 Development of SMART Pattern-changing Fabric with Effective Patterns

The hypothesis that the repeating and non-repeating patterns, the weak and intense patterns will have different influences on viewers' emotional response has been investigated in the previous chapter. In order to investigate if we can develop pattern-changing fabrics that actively influence people's emotional response, three pairs of effective pattern were directly chosen from the previous study. They are repeating pattern E1 and non-repeating pattern E2, repeating pattern F1 and non-repeating pattern F2, and weak pattern G1 and intense pattern G2. Also, two almost identical patterns D1 and D2 as shown in Figure 4-26 were used in current investigation. Although their emotional effect was not analysed in the previous study, according to the definition of weak/intense patterns, pattern D1 is a weak pattern whilst pattern D2 is an intense pattern and choosing this pattern pair is to understand how weak/intense characteristic in an identical form could influence people's emotion. These four paired patterns were then implemented in the pattern-changing effect of SMART fabrics.

As shown in Figure 4-26, fabric D has two almost identical patterned appearances, patterns D1 and D2. Both of them have regularly repeating small geometrical motifs, with the only difference being that pattern D1 is very faint (grey and white) whilst pattern D2 has the same motifs but is much clearer and more well defined (black and white). Therefore, in fabric D, the pattern changes from weak grey to intense black. Fabric G consists of two patterns G1 and G2. Both of them have symmetrical geometrical rectangular structure and contain regularly repeating diamond shapes. The difference between them is that pattern G1 has smaller diamond shapes compared to pattern G2, so that pattern G1 is small, loose and weak, whilst pattern G2 is larger, better defined and more intense than G1. Therefore, the pattern-changing effect of fabric G is the change from small and weak to large and intense pattern. In fabric E, both patterns contain small square shapes. The difference is that pattern E1 is symmetrical with continuously repeating squares, whilst pattern E2 has an asymmetrical structure with randomly arranged square and rectangular shapes, some of which are filled with intense black colour. Therefore, fabric E changes its pattern effect between being continuous, regular and symmetrical to an asymmetrical and irregular intense block. Finally, fabric F has two patterns of larger square shapes. Pattern F1 is a symmetrical pattern with regularly repeating square shapes, whilst pattern F2 contains the same squares as F1 but they are non-repeating and some filled with black intense colour or smaller squares within. As a result, pattern F2 is more complex than pattern F1 and non-asymmetrical. The pattern-changing effect of fabric F is therefore a change between being simple and very symmetrical to being complex and symmetrical.

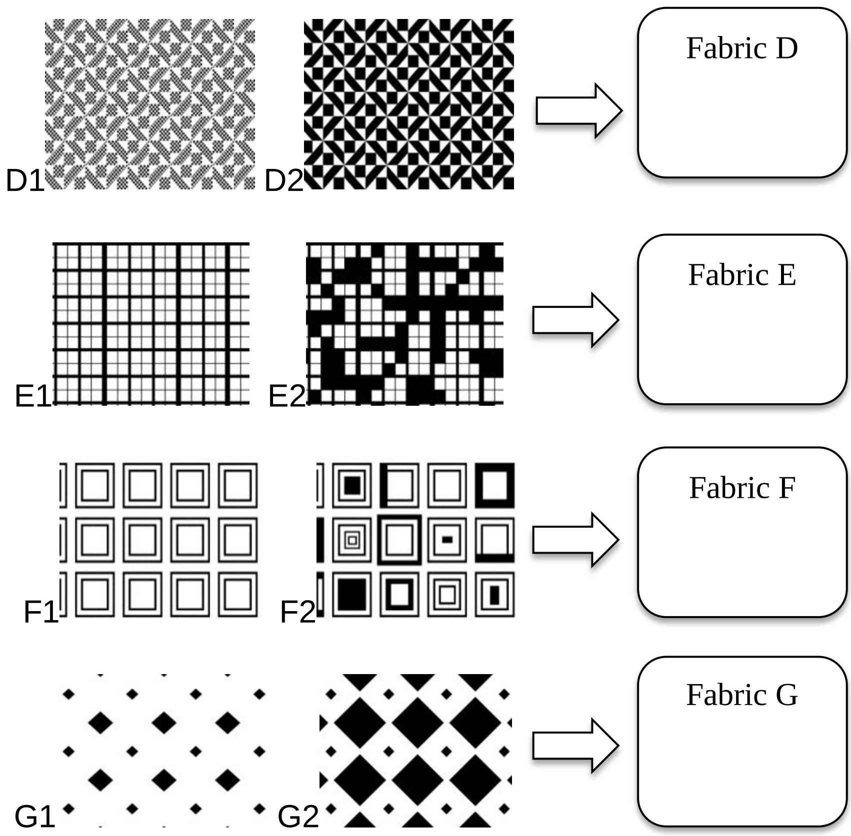


Figure 4-26 Four pairs of representative patterns of SMART pattern-changing fabrics.

4.7.1 *Designing the pattern-changing effect on fabric*

- Fabric D

Fabric D is designed to transform its appearance between paired pattern D1 and D2. As seen in Figure 4-27, the transformation is caused by a changing section inside the pattern. When the changing section is in black colour, the pattern appears as pattern D2; when the changing section turns to white colour, the pattern appears as the pattern D1.

During the fabric production, an ordinary yarn of white colour is used for knitting the white section of pattern D1 and another ordinary yarn in black colour for the black section of pattern D1; the changing section embedded inside the pattern is done by knitting with a SMART composite yarn, so that the changing section attains the colour-changing effect. When the SMART composite yarn changes to black colour, the fabric changes to pattern D2; when the SMART composite yarn changes its colour to white, the fabric change to pattern D1. Hence, Fabric D produces different patterns and according to temperature it can switch the pattern from intense to weak and back to intense.

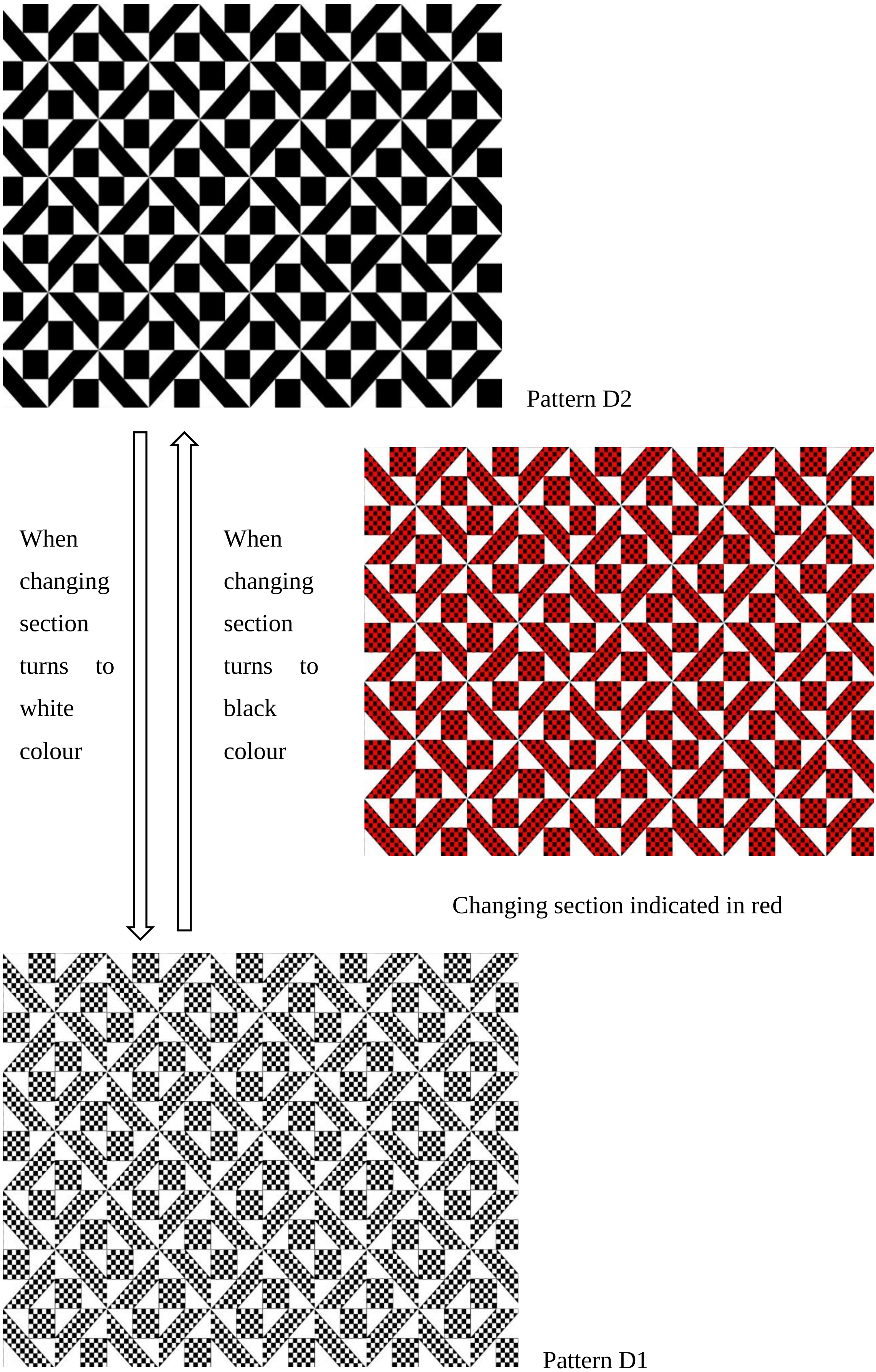


Figure 4-27 Principle of the pattern-changing effect of Fabric D.

- Fabric E

The pattern-changing effect of Fabric E is devised by transformation between a repeating pattern and a non-repeating pattern. As shown in Figure 4-28, E2 is a non-repeating pattern and E1 is a repeating pattern. The changing section inside the pattern generates the pattern-changing effect. When the colour of the changing section is in black, the pattern appears as in E2; when the colour is in white, the pattern appears as in E1. During the fabric production, the black and white section of pattern E1 are knitted by two ordinary yarns in black and white colours, and the changing section embedding inside pattern is done by knitting with a SMART composite yarn, so that the section attains the colour-changing effect. When the SMART composite yarn changes its colour to black, the fabric appears as pattern E2; when the SMART composite yarn changes its colour to white, the fabric presents as pattern E1. Therefore, Fabric E produces visually different patterns and based on temperature it can change from a non-repeating to a repeating pattern.

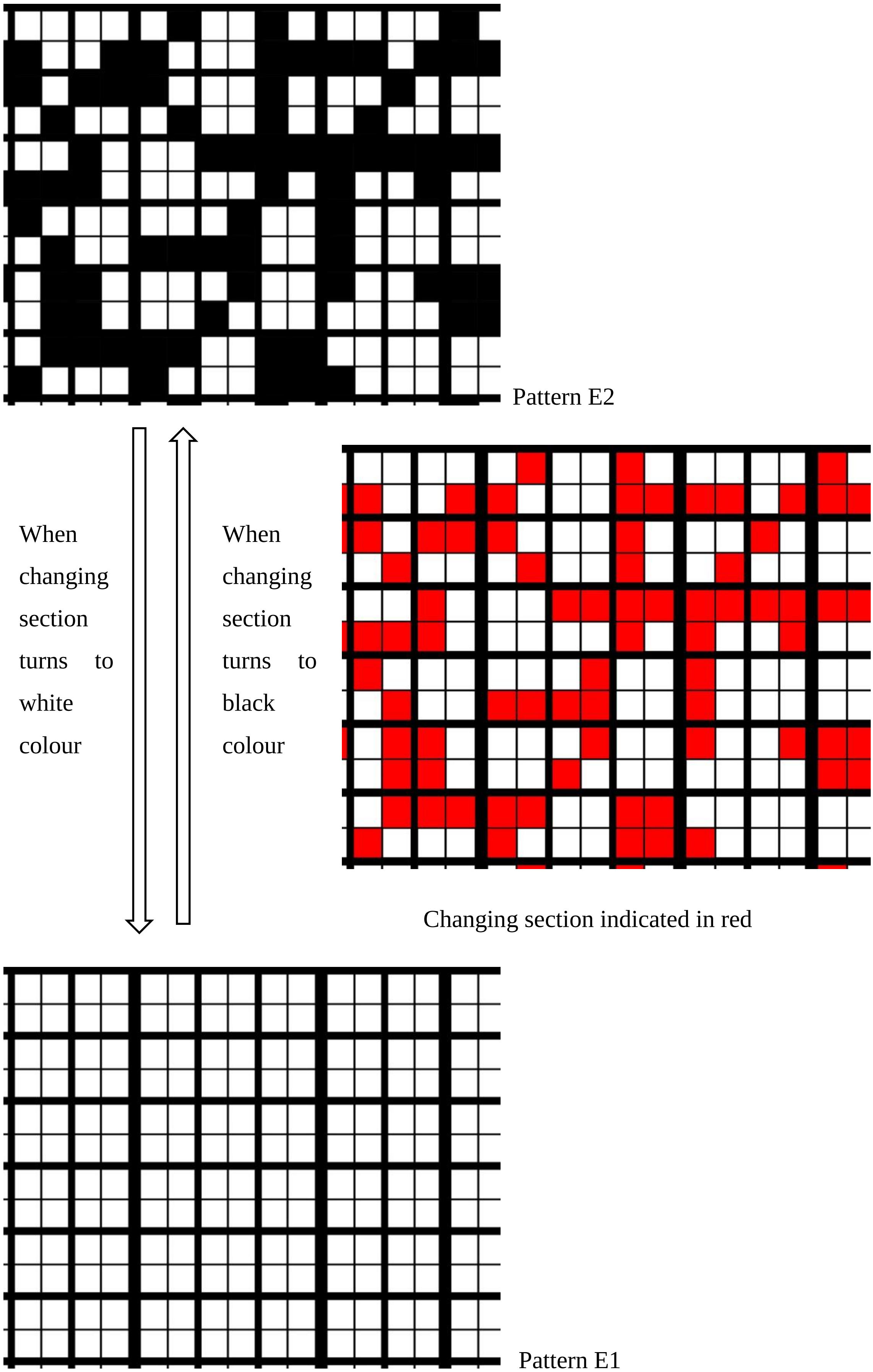


Figure 4-28 Principle of the pattern-changing effect of Fabric E.

- Fabric G

Fabric G is designed to transform its appearance between paired pattern G1 and G2. As shown in Figure 4-29, one pattern is in G2 which is an intense pattern; the other pattern is in G1 as a weak pattern. A changing section inside the pattern is controlling the changes between these two patterns. When the changing section is black in colour, the pattern shows as in G2; when the changing section is white in colour, the pattern shows as in G1. During the fabric production, the black and white section on pattern G1 are knitted by two ordinary yarns in black and white colours, and the changing section embedded inside the pattern is done by knitting with a SMART composite yarn described, so that the section attains the colour-changing effect. When the SMART composite yarn is black in colour, the fabric appears as pattern G2; when the SMART composite yarn is white in colour, the fabric presents as pattern G1. Therefore, Fabric G produces visually different patterns and base on temperature it can changes from an intense pattern to a weak pattern.

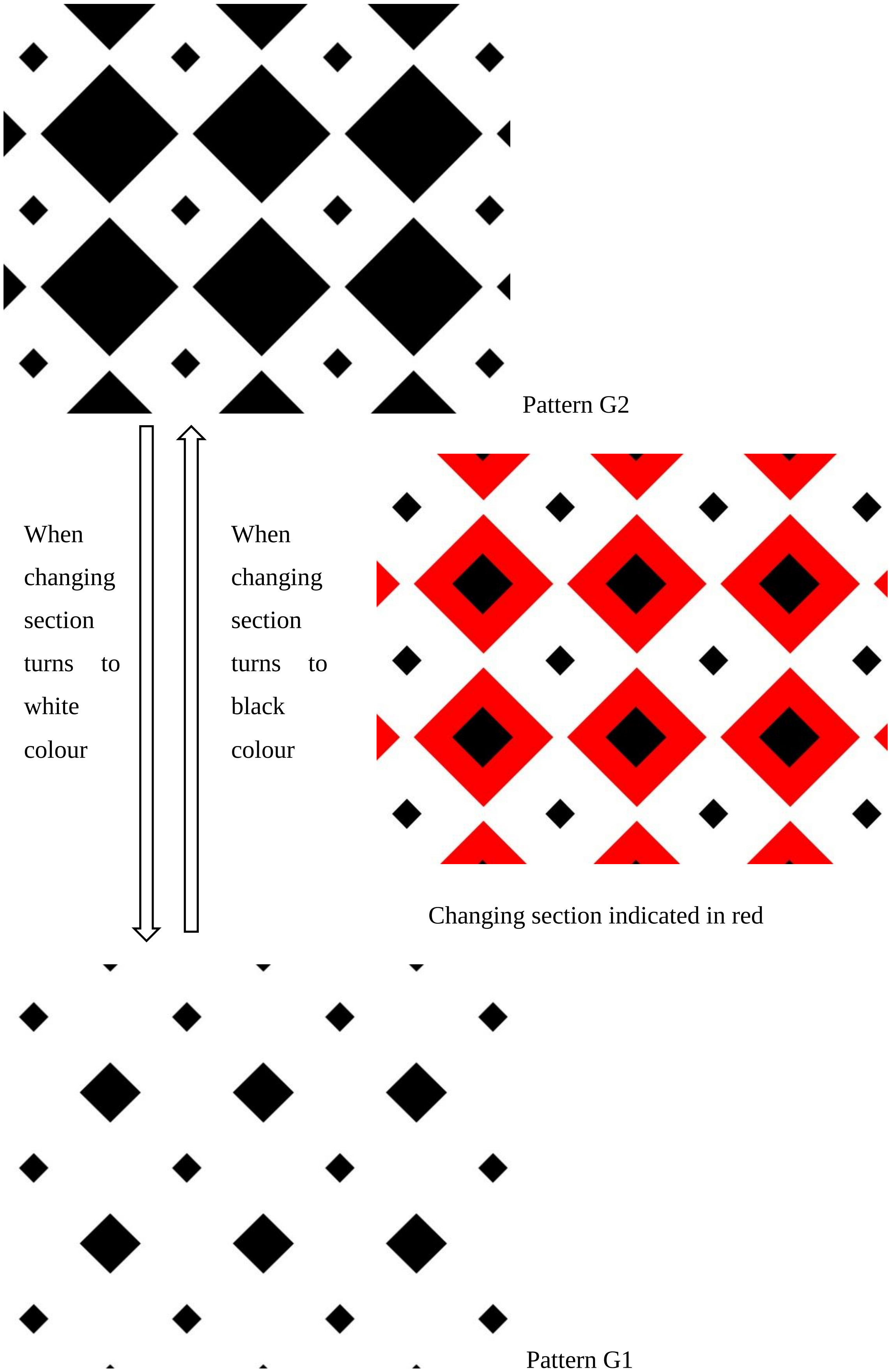


Figure 4-29 Principle of the pattern-changing effect of Fabric G.

- Fabric F

Fabric F is designed to generate two different patterns; a non-repeating asymmetrical pattern and a symmetrical repeating pattern. As shown in Figure 4-30, the pattern in F2 is a non-repeating pattern and the pattern in F1 is a repeating pattern. The pattern transformation is caused by a changing section inside the pattern. When the changing section is black in colour, the pattern appears as pattern F2, when the section is white in colour, the pattern appears as pattern F1. During the fabric production, the black and white section on pattern F1 are knitted by two ordinary yarns in black and white colours, and the changing section embedded inside the pattern F1 is done by knitting with a SMART composite yarn, so that the changing section attains the colour-changing effect. When the SMART composite yarn is black in colour, the fabric appears as pattern F2; when the SMART composite yarn changes its colour to white, the fabric presents as pattern F1. Therefore, Fabric F produces different patterns and depending on temperature it can changes from a non-repeating to a repeating pattern.

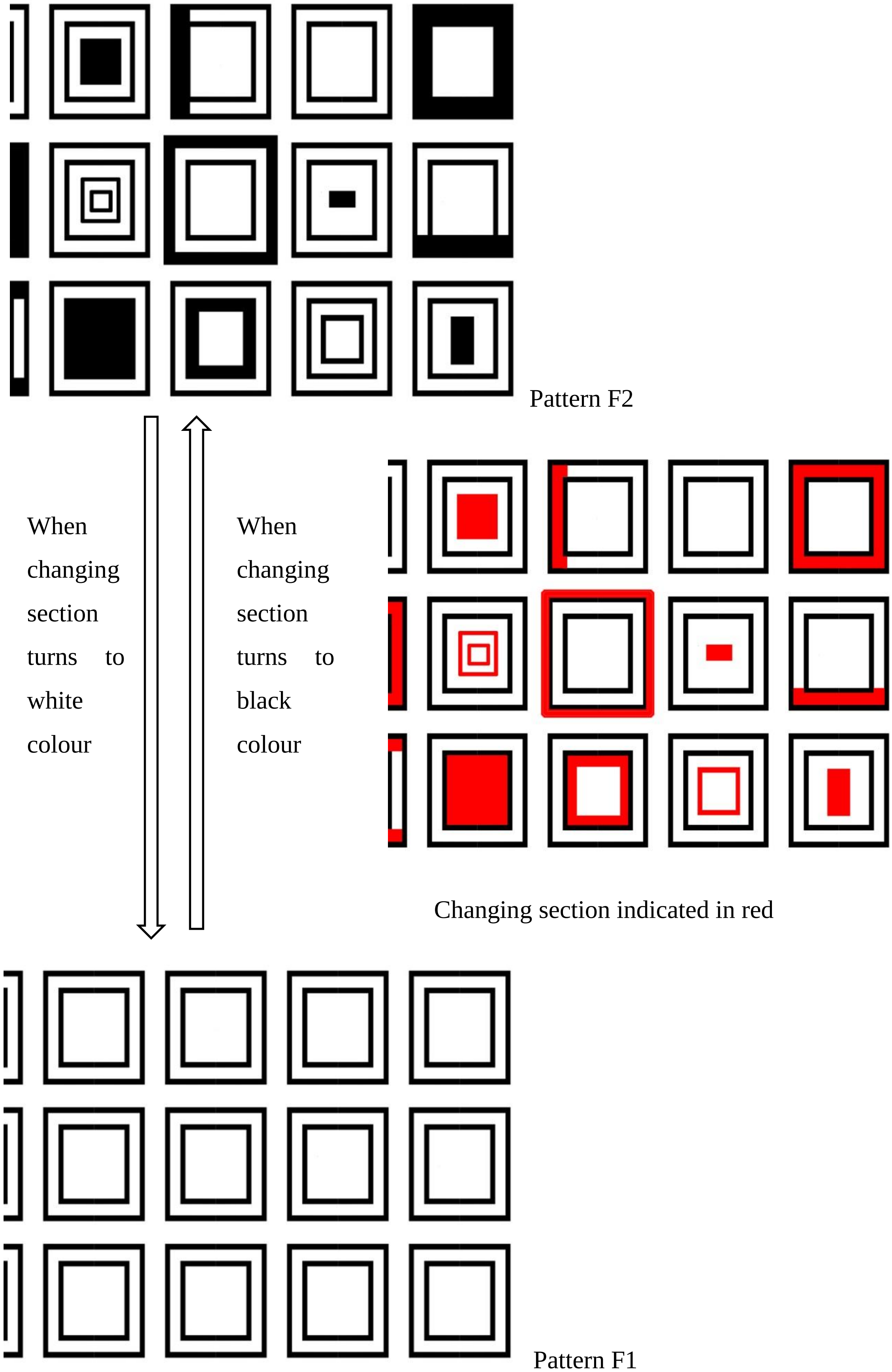


Figure 4-30 Principle of the pattern-changing effect of Fabric F.

4.7.2 *Pattern-changing fabric production*

4.7.2.1 Materials

A SMART composite yarn was developed for producing the changing section of the pattern in the fabric. It was the coloured SMART composite yarn sample D. A 112 Tex wool in white colour was used for the white section of the pattern, and a combination of one ply of 50 Tex wool in black colour and a ply of 50 Tex wool in grey colour was used for the black section of the pattern. Using this combination enables the yarn to have a mix of dark grey and black colour instead of being purely black, which is close to the colour of the SMART composite yarn. Therefore, to match the pattern requirements, the combination of two yarns was needed, as described.

4.7.2.2 Size of the pattern

Each pattern of the pattern-changing fabric was designed to have the same size as the pattern shown on the computer screen in the experiments described of Chapter 3. Firstly, each pattern was printed on paper in the same size as the one on the computer screen. The size of every colour section of the pattern was measured. The optimum stitch density of the fabric was calculated through testing samples, so 4 wales per cm in width and 4.5 courses per cm in height was achieved. Then, according to stitch density, the size of the pattern on the fabric was calculated in the numbers of wales and courses. For example, a pattern is 30.5 cm in width and 24.5 cm in height, so the pattern of the fabric is 122 wales in width and 111 courses in height. The information of the pattern sizes were then used in the CAD drawing process and the software of the knitting machine, the detail of which is given below.

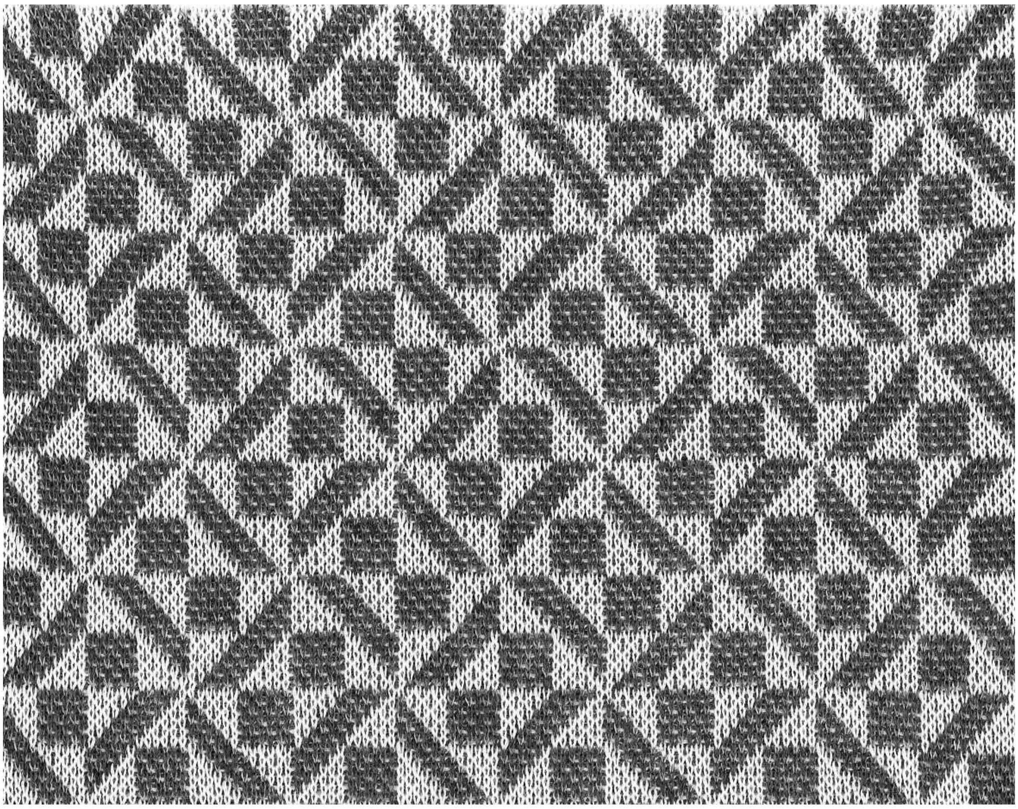
4.7.2.3 Pattern-changing fabric production

Four pattern-changing fabrics were produced on an 8 gauge Shima Seiki SES 122 S knitting machine. Preliminary trials were conducted to ascertain optimal machine settings. The production speed at 0.5 metre per second and the tension setting of the machine at 28 were found to be appropriate. The design structure of the samples was a three colour bird's eye jacquard. Choosing this structure is because that the fabric is composed of three different yarns and the three bird's eye jacquard structure eliminates floats where a yarn is selected to miss in the stitches. The patterns were firstly drawn in the CAD software of the knitting machine and then sent to the machine for fabric production. The details of the CAD design information is reported in Appendices B.6 to B.9.

4.7.3 *The pattern-changing effect of the SMART fabrics*

Two patterned fabric appearances of Fabric D are shown in Figure 4-31. At a room temperature of 20^{o}C, the fabric has an appearance as in the first image; when its temperature increases to 31^{o}C and over, it changes its appearance as in the second image. The patterns of two appearances look almost identical, but a difference is that the first pattern has higher contrast compared to the second one, therefore it is visually more intense as opposed to a non-intense and weak pattern. Fabric E presents two patterned appearances, which are shown in Figure 4-32. The first one appears at room temperature of 20^{o}C and the second one appears when the temperature is over 31^{o}C. The difference of these two patterns is that the first one has an asymmetrical non-repeating pattern with randomly located black squares, while the second one has a symmetrical repeating pattern. Fabric F has two patterned appearances as shown in Figure 4-33. The first image is when the fabric is exposed to room temperature of 20^{o}C and the second image is when the temperature is over 31^{o}C. The pattern effect between the two patterned appearances is that the first one has larger diamond shapes, which causes the pattern to look intensive; while the second pattern has smaller diamond shapes, producing a loose pattern structure, therefore having visually less impact. The patterned appearances of Fabric G are shown in Figure 4-34. At room temperature of 20^{o}C, the fabric appears as in the first image; when the temperature is over 31^{o}C, it changes to the second image. The patterns are identical and both have regular squares. But, in the first pattern each square has different content, which makes the pattern have non-repeating units; in the second pattern each square is the same, and has repeating units. In summary, Fabrics D and G have a pattern-changing effect between weak and intense patterns; and Fabrics E and F change their patterns from repeating to non-repeating.

The pattern-changing effect on these fabrics depends on yarn colour-changes in the pattern area, which is knitted using the SMART composited yarn developed for this purpose. This colour-change yarn function is able to be controlled by the supply of the electric current. However, several short circuits were found in different areas of the fabrics, which led to discontinuity of electric current in those areas and no colour-changes on the yarn, therefore loss of the pattern-changing effect. The reason causing the short circuit has been investigated. The electrical conductivity of the composited yarn depends on the copper wire inside the yarn. The copper wire is conductive, but insulated on its surface by the nonconductive coating material and by also the thermo-chromic coating during yarn coloration. Some of these coatings were inspected to be scrapped off during fabric production, so that the copper wire lost its insulation. Inside the fabric, when two or more non-insulated areas touched each other, the electric short circuit occurs. In order to prevent this problem, the fabric production speed on the machine could be decreased for reducing the friction generated between the knitting needles and the composited yarn, or it could strengthen the insolating surface of the copper wire or the thermo-chromic coating of the composited yarn by using appropriate materials and techniques. However, these are outside the aim of the current research, and therefore further studies are required to solve this problem.



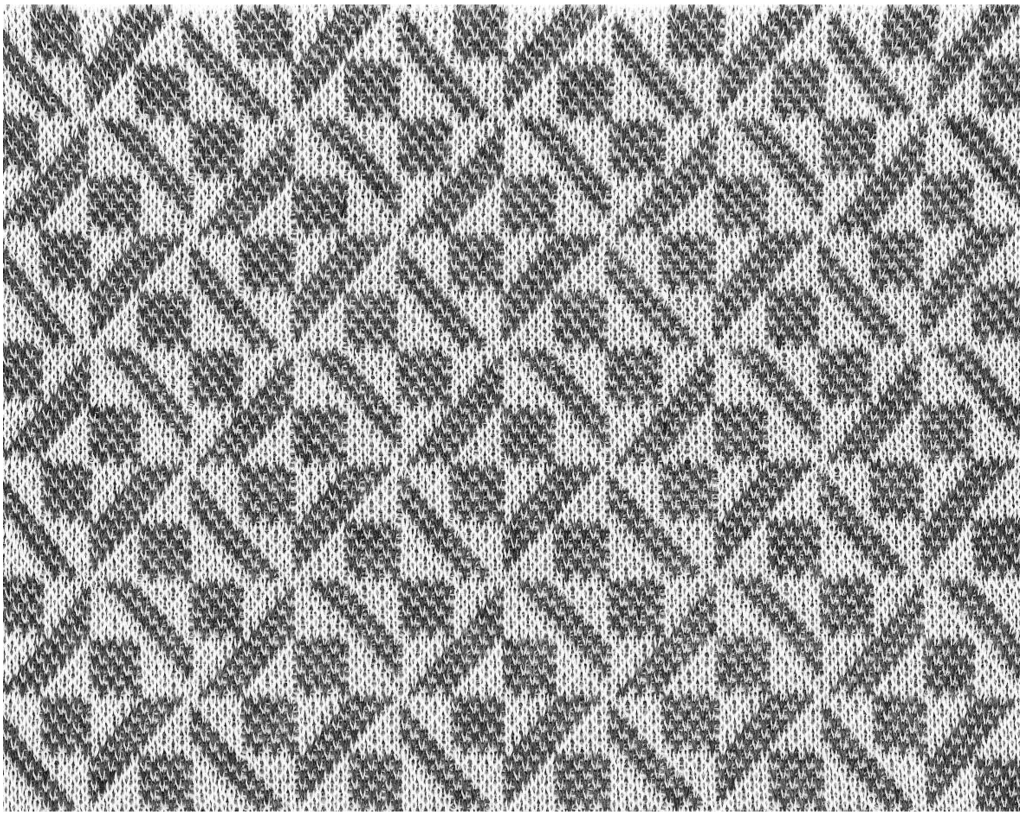


Figure 4-31 Photograph of two patterned appearances of pattern-changing fabric D.

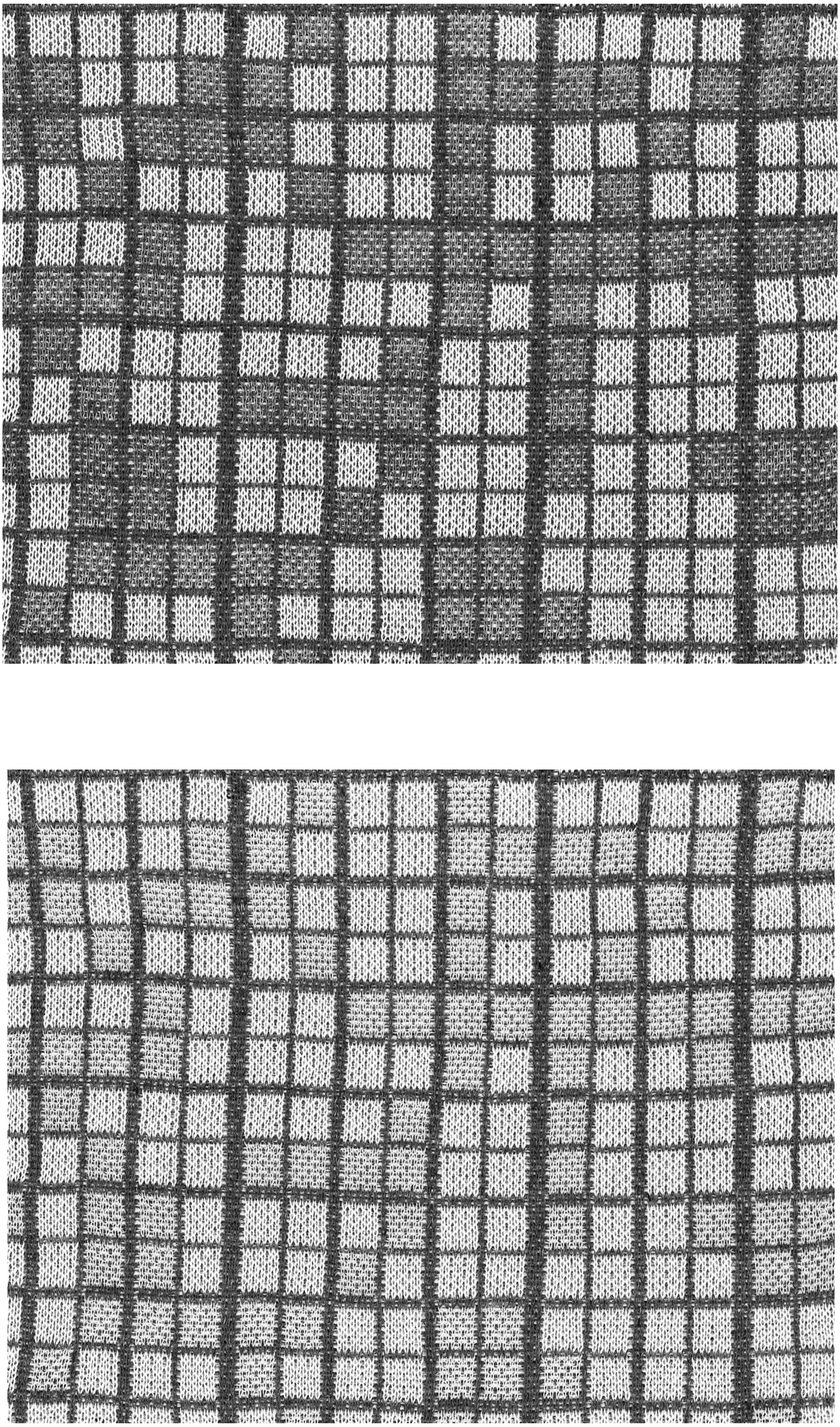


Figure 4-32 Photograph of two patterned appearances of pattern-changing fabric E.

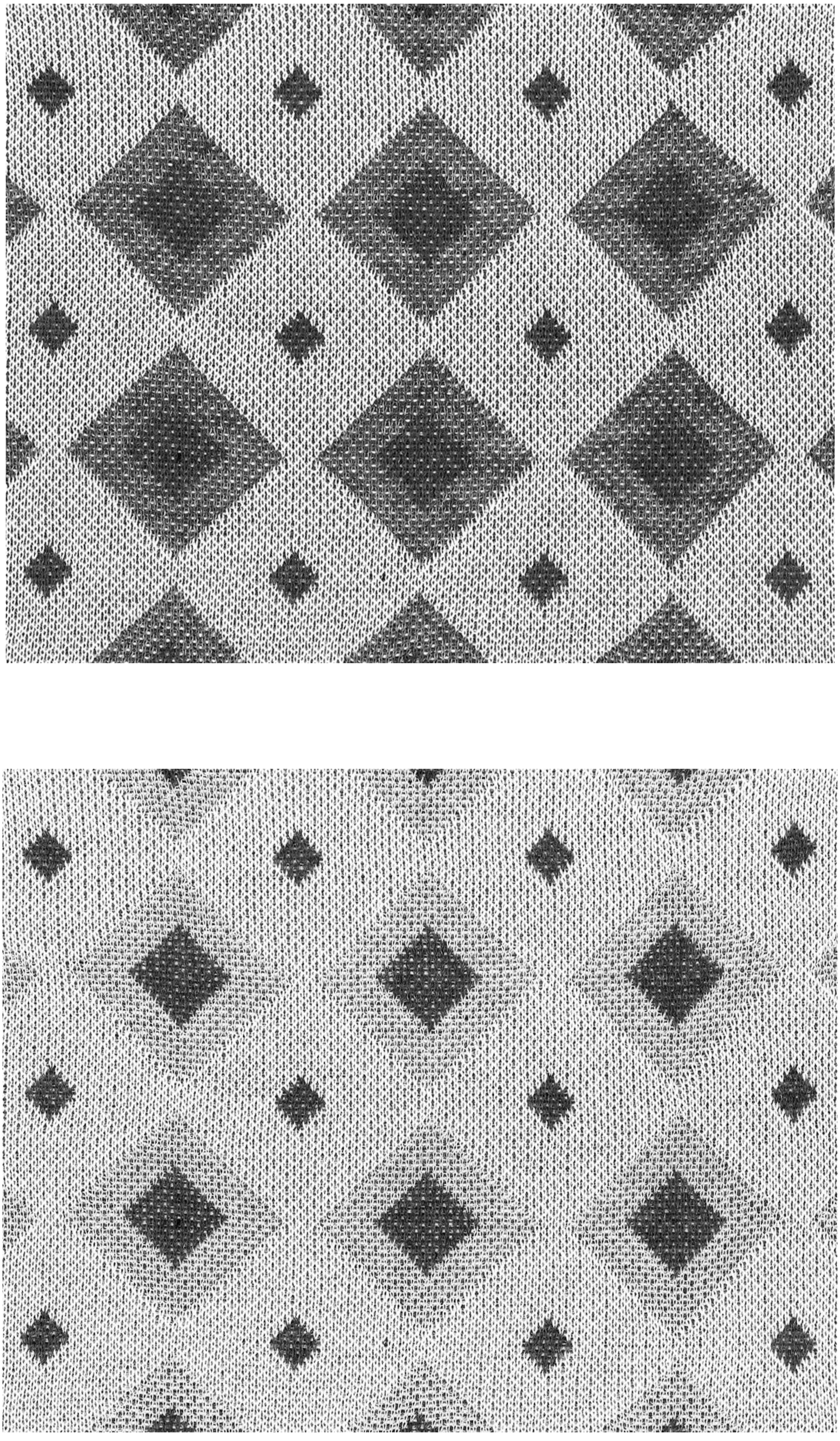


Figure 4-33 Photograph of two patterned appearances of pattern-changing fabric G.

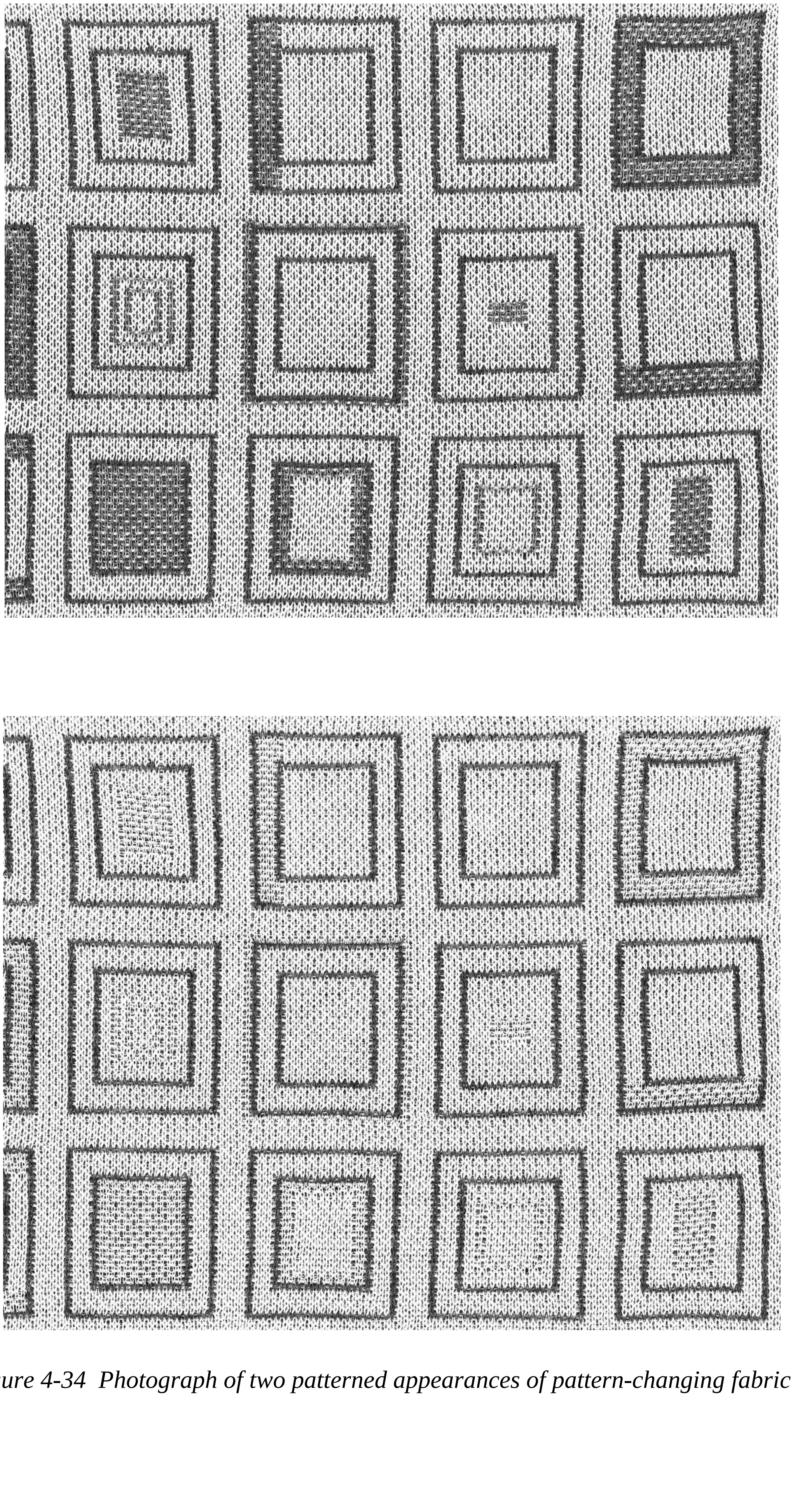


Figure 4-34 Photograph of two patterned appearances of pattern-changing fabric F.

4.8 Summary and Discussion

Pattern-changing fabric has been defined and established as an aesthetic effect by using SMART colour-changing electrochromic yarns. Five samples of pattern-changing fabrics were produced by both knitting and weaving processes. Their electronically controlled pattern-changing functionality was established achieving initial pattern changing design concepts. Their functionality is mainly generated by the SMART electrochromic yarn. It is a special textile material that can change its colour upon the application of an electric current. It has been developed from a conceptual yarn design and selection of materials, and their development through yarn spinning and colouration. Yarn spinning was conducted on a commercial fancy yarn machine by optimising its process parameters and the yarn colouration developed a new method to suit the yarn unique features. The SMART yarn was then exploited for fabric production. Optimising yarn feeding and taking down tension, the SMART yarn was successfully used for knitting fabrics on both manual and computer controlled knitting machine; as well as weaving fabrics on a manual Dobby floor loom. The SMART attributes of these fabrics were preserved and enhanced in the finished fabrics. These SMART yarns experienced some processing difficulties. Despite optimising the feeding and tensions during yarn spinning, some loose loops of the copper wire were still formed on the surface of the SMART yarn during the spinning process. This is caused by the different mechanical behaviours of the copper wire and the normal textile yarn, which could not be optimised any further under the Gemmill and Dunsmore fancy yarn machine, i.e. there was a limit to how much we could reduce the tension of the copper yarn without affecting the minimum tension of the normal yarn to allow them to blend during spinning. The optimum settings on the machine only minimised this flaw. The other difficulty is in yarn colouration. The spray coating method was used to transfer the thermo-chromic pigment on the SMART yarn, proved successful but, a little amount of some sections of the copper wire were not uniformly coloured and the pigment added a little amount of rigidity onto the SMART yarn. Despite these difficulties, however, the SMART functionality of the composite yarn was successfully produced and realised design requirements. There are two functions of the SMART electrochromic yarn. One is its thermo-chromic function at ambient temperature and free from any electric current application. For example, the SMART composite yarn D remains black in colour when the temperature of its environment is less than 31^{o}C, and it changes to a white colour when the temperature increases over 31^{o}C. Thus its colour-change effect reacts to the changes of environmental temperature. The other function of the SMART yarn is its electronically controlled colour-changing ability. When the environment temperature remains constant and less than 31^oC, the yarn can change from black colour to white colour under the control of an electric current, and recovers back to black colour when disconnected from it. Consequently the colour-change effect of the yarn reacts to temperature and belongs to the generic types of thermochromic materials and more specifically thermochromic yarns. The pattern-changing fabrics produced from these yarns also contain the same thermochromic functions. One is the pattern-changing effect activated by the increase of the ambient temperature above 31^oC. The other one is that, in a constant temperature environment, the changing effect can respond to an electric current. The electronic manipulation of current supplied to the fabric is significant because it enables the pattern-changing fabric to connect with computing control so that the fabric can interact to a pre-designed scenario.

The final collection of four pattern-changing fabrics were designed and produced. They have different effective patterns, as studied in the previous chapter. Two of the samples, Fabrics E and F, have changing appearances from repeating to non-repeating patterns, and another two samples, Fabrics D and G, have changing appearances from weak to intense patterns. The transformation between the two patterns is activated by colour change of a changing section embedded inside the pattern. The changing section of the pattern is knitted by using a purpose developed SMART electrochromic yarn that is able to change colour by change of temperature. In fabric production, the samples were successfully produced on the Shima Seiki knitting machine. The pattern-changing effect of the finished samples is activated by increasing the temperature of the samples from room temperature of 20^oC to over 31^oC. By changing the temperature, two effective patterns appear on the fabric.

In the previous study, we have established the different emotional effect of repeating/non-repeating pattern and weak/intense pattern. In the current experiment, we have developed a SMART electrochromic yarn which enables us to create a changing effect of repeating/non-repeating and weak/intense patterns on fabrics. In order to investigate the capability of these fabric that can actively influence people's emotion, a further experiment was conducted to determine the emotional effect of the pattern-changing function of the fabric, which is reported in the following chapter.

CHAPTER 5 IMPLEMENTATION OF SMART PATTERN-CHANGING FABRICS AND THEIR EFFECTS ON HUMAN RESPONSE

In the previous chapter, a collection of four SMART fabrics capable of changing from one design to another was produced. Each of them can present two patterned appearances. This chapter aims to investigate the differences of people's emotional response to those two fabric patterned appearances. The research methodology is the same as the one in Chapter 3. The only difference is that now the work is implemented with real fabrics. People's emotional response and preference were calculated by subjective evaluation, which included the Self-Assessment Manikin and the 9-point hedonic scale. People's physiological reactions were measured through their brain wave activity and heart rate changes, and their psycho-physiological data were statistically analysed and interpreted. The significant differences of the responses between two paired patterns of a SMART fabric were determined by the statistical hypothesis testing technique. When differences were established, the confidence intervals of the mean of these differences were computed and analysed. The combination of subjective evaluation and physiological measures reveal a great deal of people's responses between the two patterned appearances of a SMART fabric, therefore to determine the capability of its pattern-changing effect in the interaction with a viewer's emotional response. Furthermore, based on the literature review some pattern shape, form, corner, size and noise have an effect on our visual response. In the previous study, we only focused on the emotional effect of pattern, therefore in the current chapter we also investigated whether change of the pattern of a SMART fabric can affect the viewer's visual response. Participants' visual response was directly measured in their visual brain by the event-related potential (ERP) method. The amplitude and latency of the ERP component evoked by the viewing of the two paired patterns of a SMART fabric were analysed and compared, so that differences in people's visual response to the pattern-changing effect can be revealed.

5.1 Experiment Design

5.1.1 *Participants*

The 20 participants in the experiment of Chapter 3 took part in the current experiment. Their details are reported in Chapter 3, section 3.2.1.

5.1.2 *Fabric stimuli*

The two patterned appearances of every pattern-changing fabric as shown in Figures 4-31 to 4-34 in Chapter 4 were scanned into a computer and saved as digital images. Each of them was named as an individual fabric stimulus as shown in Figure 5-1. During the experiment, each fabric was presented at the centre of a 19-inch monitor screen in a grey colour background. The displaying size of every fabric was 305mm in width and 245mm in height. All fabrics were presented with the same brightness setting. The participant sat in front of the monitor at 1400mm distance during the experiment, so that the visual angle of the fabric stimuli was 12.4 degrees in the horizontal and 10.0 degrees in the vertical dimensions.

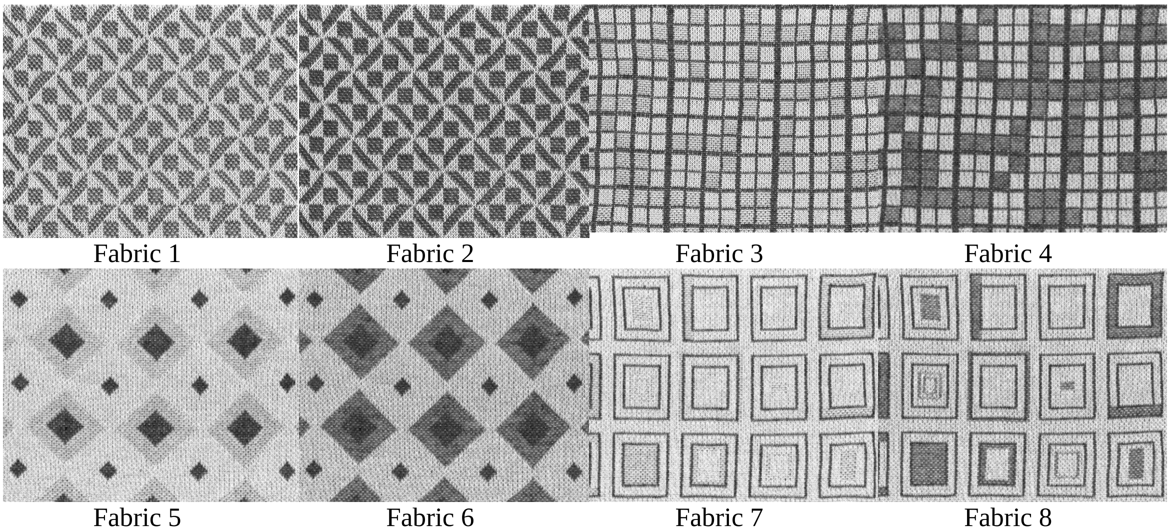


Figure 5-1 Eight fabric stimuli used in the experiment.

5.1.3 *Experimental slides*

Experimental slides used in the current experiment follow the same as Chapter 3, section 3.2.3. The only difference is that the pattern stimulus was replaced by the fabric stimulus. The order and duration of the slides were pre-programmed by bespoke scripts in the "Presentation" software. The coding of these scripts is reported in Appendices C.1-C.2.

5.1.4 *Experimental procedure*

The procedure of the experiment follows the same as Chapter 3, section 3.2.5. It includes experimental preparation, experimental part 1, in which each participant's EEG and ECG signals were recorded while they were viewing the fabric stimuli, and experimental part 2, in which the participant was asked to use the Self-reported Rating Scales as described in Chapter 3, section 3.2.4 to evaluate his/her emotional response and preference to the fabric stimuli.

5.2 Data Acquisition and Processing

Each participant's brain response was determined by EEG signals acquired through the 19 electrodes contained in the EEG cap as described in Chapter 3, section 3.3.1.1. The EEG signal pre-processing was performed on the EEG signals following the same method as in Chapter 3, section 3.3.1.2, which includes synchronisation of the EEG signals and the log files of the slides in EEGLAB, extraction of the EEG signals corresponding to the viewing of the 8 fabrics and correction of the artefacts in the extracted EEG signals. The extracted EEG signals contain an epoch starting 2 seconds before the fabric onset to 10 seconds after the fabric presentation on screen. Participants' absolute EEG frequency band (Delta, Theta, Alpha, Beta and Gamma) powers corresponding to the viewing of the 8 fabrics were calculated following the same method as in Chapter 3, section 3.3.1.2. These results were then imported to Minitab for further statistical analysis.

Participants' heart rate changes corresponding to the viewing of the 8 fabrics were calculated from the recorded ECG signal. The signal acquisition and processing follow the same as Chapter 3, section 3.3.2. The twenty participants' heart rate changes responding to the viewing of 8 fabrics were calculated and imported to Minitab for further statistical analysis.

Participants' subjective evaluation of their emotions and preferences to the fabrics are revealed from their ratings on the Self-reported Rating Sales. The ratings were scored following the same system as Chapter 3, section 3.3.3, and the results were then imported to Minitab for further statistical analysis.

5.3 Data Analysis and Results

Data analysis aims to investigate the difference in people’s responses to the two paired fabrics as follows:

$$\text{Different} = \text{Response}_{\text{Fabric 1}} - \text{Response}_{\text{Fabric 2}},$$

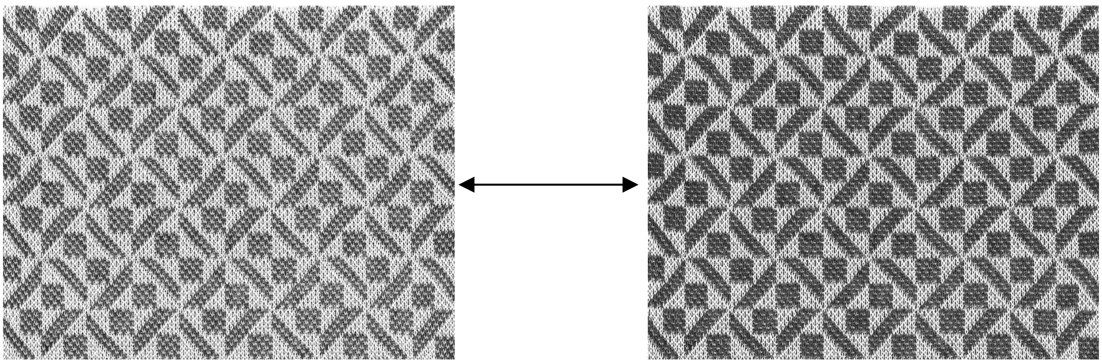
$$\text{Different} = \text{Response}_{\text{Fabric 3}} - \text{Response}_{\text{Fabric 4}},$$

$$\text{Different} = \text{Response}_{\text{Fabric 5}} - \text{Response}_{\text{Fabric 6}},$$

$$\text{Different} = \text{Response}_{\text{Fabric 7}} - \text{Response}_{\text{Fabric 8}}.$$

The mean of the difference were calculated based on the twenty participant’s experimental data by using the statistical hypothesis test and confidence interval estimation as described in Chapter 3, section 3.4.1.1. The statistical calculation was performed in people’s EEG frequency band power response, the Frontal Alpha Asymmetry index, heart rate change and subjective rating scores, which procedures follow the same as Chapter 3, section 3.4.1.2. The only difference is that in Chapter 3 people’s response to each type of pattern is presented by their averaged responses to the 8 sample patterns; whilst in the current experiment people’s response to each fabric was straightforward.

5.3.1 *Investigating the differences in people’s responses to Fabrics 1 and 2*



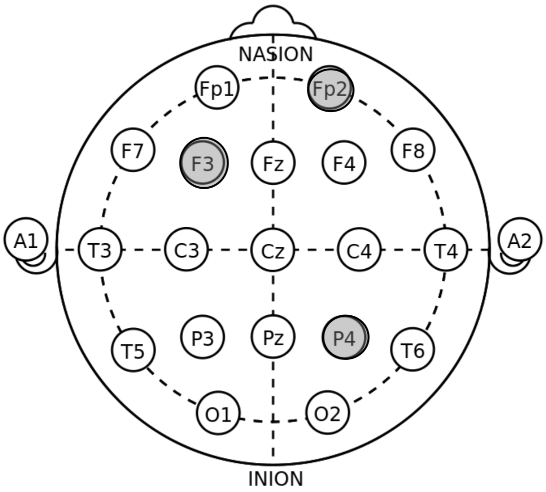
Fabric 1 Fabric 2

5.3.1.1 Frequency band power of the EEG

The differences of the 5 frequency band powers of twenty participants when responding to the Fabrics 1 and 2 are reported in Appendices C.3 – C.7. The observed significant differences of each frequency band are reported as follows.

- Delta frequency power

Significant differences in Delta power response were found in the Fp2, F3 and P4 channels, as shown in Figure 5-2. In the Fp2 channel located at the right of the pre-frontal lobe of the brain, the mean of the difference at 90% confidence level is over zero. This shows that the Fabric 1 evoked a significantly higher Delta power than Fabric 2 at this location of the brain. In the F3 channel located at the left of the frontal lobe of the brain, the mean of the differences at 88% confidence level is over zero, which shows that Fabric 1 also evoked a higher Delta power than Fabric 2 in this location of the brain. However, in the P4 channel located at the right of the parietal lobe, the mean of the difference is less than zero at 83% confidence level, which shows that Fabric 1 evoked less Delta power than Fabric 2 in this location of the brain. The Delta response in the frontal region of the brain has been found to be higher in response to emotional stimuli than neutral stimuli [168]. However, whether the emotional effect is positive or negative is undefined in the literature. Therefore, in the current investigation, the significant difference observed in the frontal region of the brain might infer that the Fabric 1 has more emotional effect than Fabric 2.



Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Fp2	20	2.10	4.99	1.12	(0.17, 4.03)	1.88	0.075

Variable	N	Mean	StDev	SE Mean	88% CI	T	P
F3	19	1.141	2.966	0.680	(0.031, 2.252)	1.68	0.111

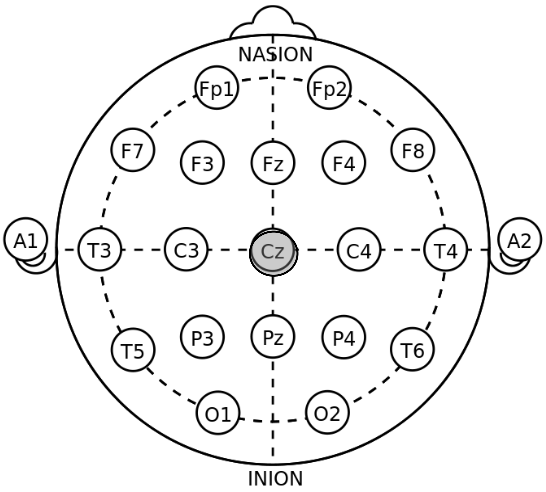
Variable	N	Mean	StDev	SE Mean	83% CI	T	P
P4	20	-1.60	4.92	1.10	(-3.17, -0.03)	-1.45	0.163

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-2 Significant differences of the brain's Delta power, when responding to Fabrics 1 and 2.

- Theta frequency power

Significant difference in Theta power response was only observed in the Cz channel, as seen in Figure 5-3. The mean of the difference is less than zero at 83% confidence levels, which indicates that Fabric 2 evoked significantly higher Theta power than Fabric 1 at the central area of the brain. The relationship between emotional process and the increased Theta power response at the central part of the brain has not been found in literature.



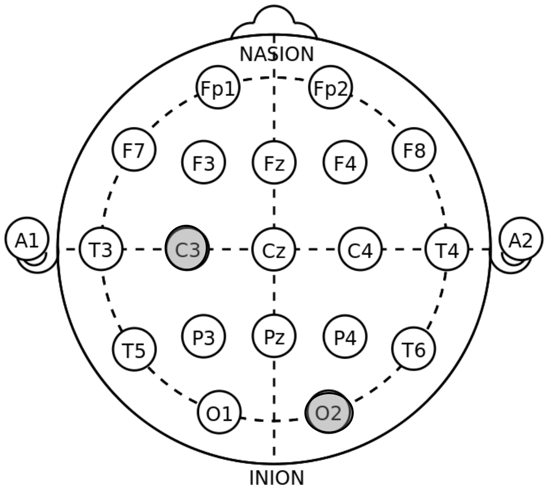
Variable	N	Mean	StDev	SE Mean	83% CI	T	P
Cz	19	-1.040	3.102	0.712	(-2.057, -0.022)	-1.46	0.161

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-3 Significant differences of the brain's Theta power, when responding to Fabrics 1 and 2.

- Alpha frequency power

Significant differences in Alpha power response were found in the C3 and O2 channels, as shown in Figure 5-4. In the C3 channel location, the mean of difference is over zero at 93% confidence level, which shows that Fabric 1 evoked a significantly higher Alpha power than Fabric 2 on the left of the centre of the brain. In the O2 channel location, the mean of the difference is over zero at 90% confident level, which shows Fabric 1 also triggered a significantly higher Alpha power than Fabric 2 on the right of the occipital lobe of the brain. The occipital lobe is the visual processing centre of the brain. The Alpha wave and the brain activity is inversely related, which means that a reduction of the Alpha wave indicates an increase of brain activity. Therefore, Fabric 2 triggers higher visual brain response than Fabric 1. In literature, the Alpha power response to the emotional process mainly focuses on the frontal EEG asymmetry, the current observation is analysed in following section of the Frontal Alpha Asymmetry index.



Variable	N	Mean	StDev	SE Mean	93% CI	T	P
C3	20	1.446	3.364	0.752	(0.002, 2.891)	1.92	0.070

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
O2	20	1.782	4.335	0.969	(0.106, 3.458)	1.84	0.082

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

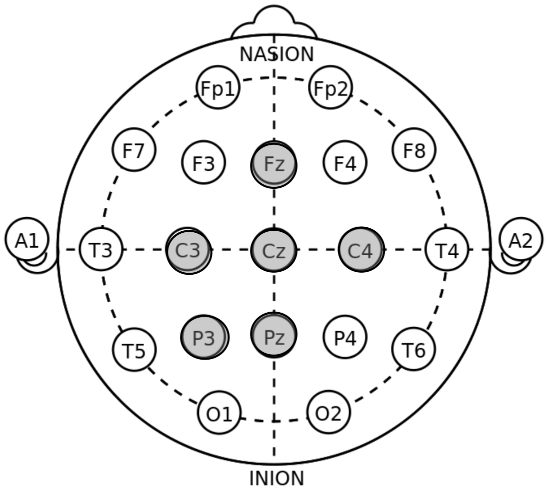
Figure 5-4 Significant differences of the brain's Alpha power, when responding to Fabrics 1 and 2.

- Beta frequency power

There is no significant difference of Beta power response evoked between Fabric 1 and Fabric 2.

- Gamma frequency power

Significant differences in Gamma power response were observed in frontal lobe, central and parietal regions of the brain, as shown in Figure 5-5. In the Fz channel location, the mean of the difference at 80% confidence level is over zero, which shows that Fabric 1 evoked significant higher Gamma power than Fabric 2 at the centre of the frontal region of the brain. In the C3, Cz and C4 channel locations, the mean of the difference is over zero at 85%, 90% and 89% confidence levels. These results show that Fabric 1 evoked significantly higher Gamma power than Fabric 2 over the central region of the brain. In the Pz and P3 channels locations, the mean of the difference is over zero at 88% and 90% confidence levels, which shows Fabric 1 also triggered higher Gamma power in these regions of the brain. Gamma power has been found to be larger in response to negative emotional stimulation compared with neutral stimulation [80, 153, 154]. In the current measurement, the significant difference found in the frontal, central and parietal regions of the brain might infer that Fabric 1 has an unpleasant effect on people's emotional response.



Variable	N	Mean	StDev	SE Mean	80% CI	T	P
Fz	20	0.463	1.528	0.342	(0.009, 0.917)	1.35	0.191

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
C3	20	0.866	2.452	0.548	(0.043, 1.688)	1.58	0.131

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Cz	20	0.767	1.937	0.433	(0.017, 1.516)	1.77	0.093

Variable	N	Mean	StDev	SE Mean	89% CI	T	P
C4	20	0.631	1.634	0.365	(0.018, 1.243)	1.73	0.101

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
P3	20	0.751	1.831	0.409	(0.043, 1.459)	1.83	0.082

Variable	N	Mean	StDev	SE Mean	88% CI	T	P
Pz	20	0.748	2.045	0.457	(0.003, 1.492)	1.63	0.119

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-5 Significant differences of the brain's Gamma power, when responding to Fabrics 1 and 2.

5.3.1.2 The Frontal Alpha Asymmetry index

The Frontal Alpha Asymmetry indices of twenty participants corresponding to Fabric 1 and 2 are reported in Appendices C.8 – C.9. The confidence intervals of the mean of the Frontal Alpha Asymmetry index of the fabrics at 80% confidence level are shown in Figure 5-6. In the cases of both fabrics, the mean of the Frontal Alpha Asymmetry index is undefined, neither positive nor negative, and therefore they have no significance, revealing no population approach/withdrawal related emotion in either Fabric 1 or 2.

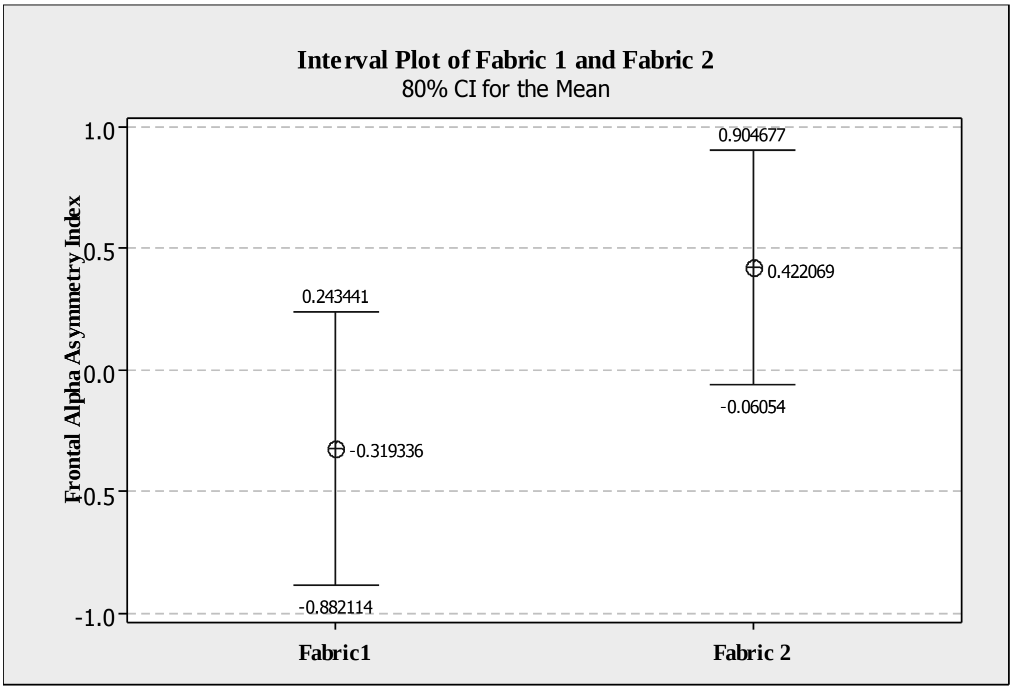


Figure 5-6 The Frontal Alpha Asymmetry index of Fabrics 1 and 2.

5.3.1.3 Heart rate changes

The heart rate changes of the twenty participants on each time window when responding to Fabrics 1 and 2 are reported in Appendices C.10 - C.11. The mean of the heart rate change to Fabric 1 was calculated and the statistical results are shown in Figure 5-7. The signficant result was observed in the initial three seconds of the heart rate response. The mean of the heart rate change of this period is over zero at 85% confidence level. This result shows that viewers' heart rate response to Fabric 1 in the initial three second period was an acceleration compared to the baseline period. In other time windows, the mean of the heart rate change is undefined, neither postive nor negative, and therefore it has no signficance. The mean of the heart rate change responding to the viewing of Fabric 2 is shown in Figure 5-8. At 90% confidence level, the mean of the heart rate change is less than zero, which shows that viewers' heart rate response to Fabric 2 was a deceleration compared to the baseline heart rate.

The difference of viewers' heart rate change responses between Fabrics 1 and 2 was caculated and the sample data of the twenty participants are reported in Appendix C.12.

At 95% confidence level, the mean of the difference of each time window is shown in Figure 5-9. A signficant difference was observed in the initial 5 seconds, in which the mean of the difference is over zero. This result shows that viewers' heart rate response to Fabrics 1 and 2 is significantly different in the initial period, in which a heart rate acceleration to Fabric 1 and deceleration to Fabric 2. Heart rate deceleration has been found to occur during human oriental response, leading to improve the stimulus intake to which the individual is attending; heart rate acceleration occurs in the defensive response that reduces sensitivity to unpleasant stimuli [2, p429-432]. Therefore, the current result might infer that Fabric 1 has an unpleasant effect on viewers' response.

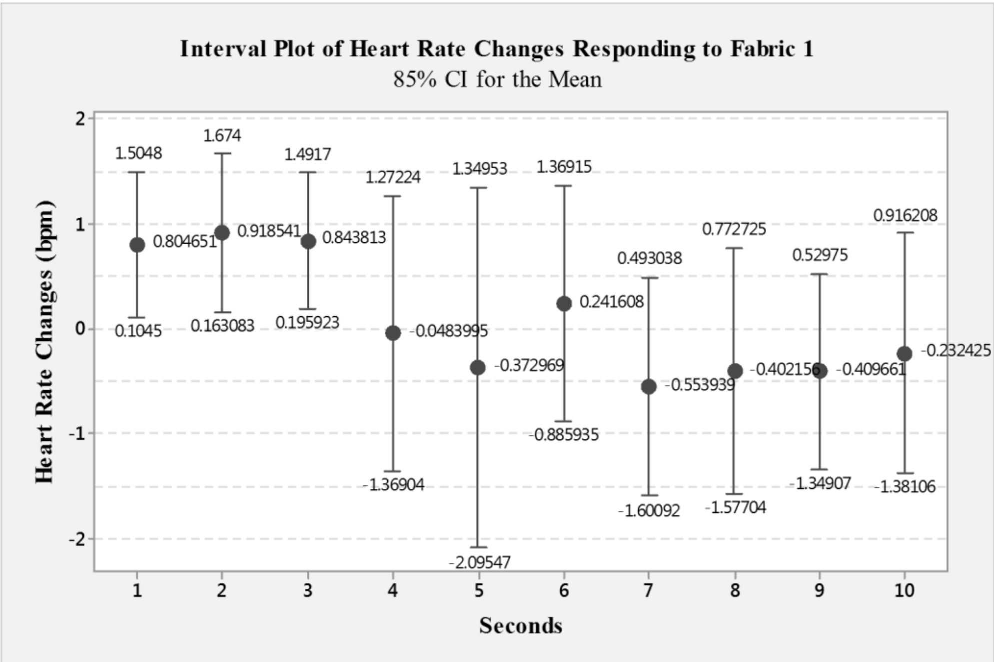


Figure 5-7 People's heart rate changes responding to the viewing of Fabric 1.

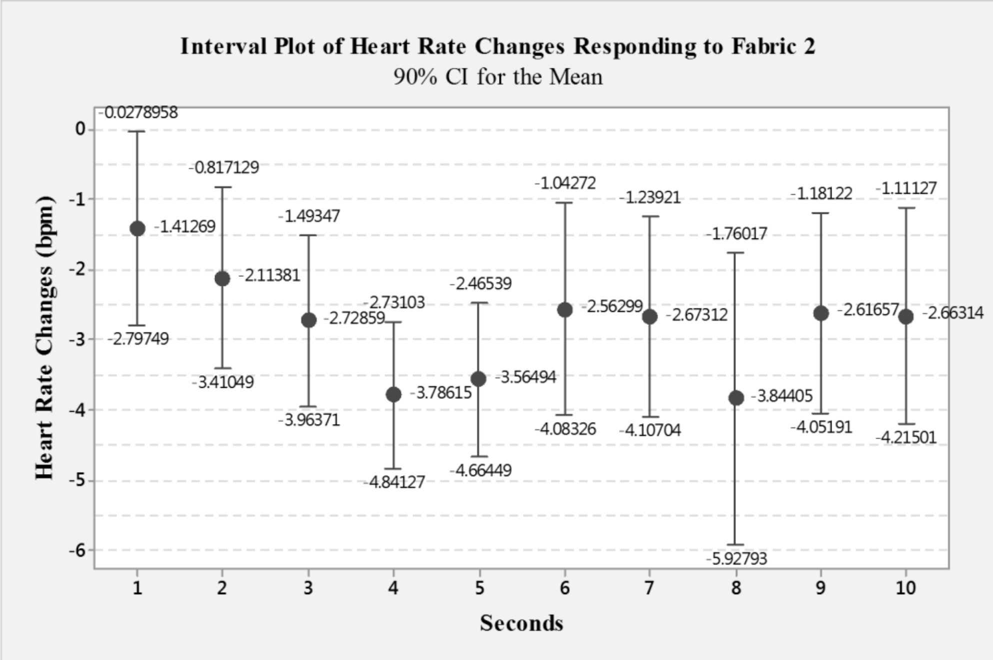


Figure 5-8 People's heart rate changes responding to the viewing of Fabric 2.

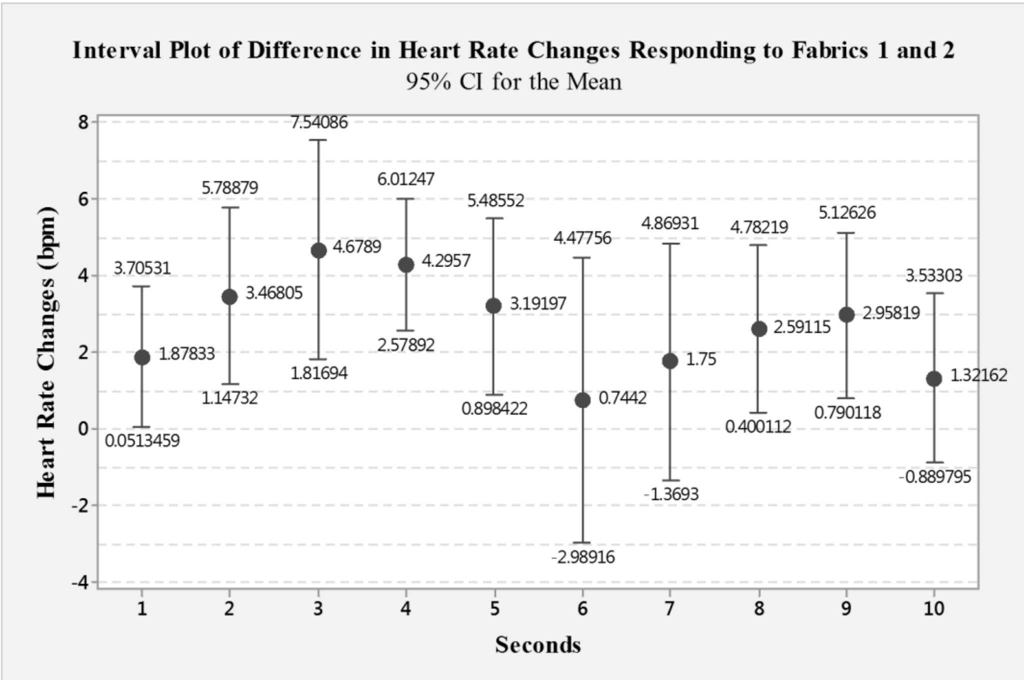


Figure 5-9 Differences of people's heart rate changes when viewing Fabrics 1 and 2.

5.3.1.4 Subjective analysis

The rating scores by the twenty participants of the Valence, Arousal and Likert scales to Fabrics 1 and 2 are reported in Appendix C.13. One participant's rating scores on the three scales were removed because they were found to be unsuitably biased. The difference between the rating scores of Fabrics 1 and 2 was calculated on each scale. At 80% confidence level, the means of the differences are presented in Figure 5-10. The significant differences were found in the Valence, Arousal and Likert scale. In the Valence scale, a confidence interval estimation at 90% confidence level shows the following:

Mean = -0.556,

Standard Deviation = 1.294,

Standard Error of the Mean = 0.305,

Confidence interval between -1.086 and -0.025, T=-1.82 and p-value = 0.086.

It can therefore be concluded that Fabric 2 is rated as more pleasant than Fabric 1 at a significantly high confidence level at 90%. In the Arousal scale, a confidence interval estimation at 90% confidence level shows the following:

Mean = -0.737,

Standard Deviation = 1.759,

Standard Error of the Mean = 0.404,

Confidence interval between -1.437 and -0.037, T= -1.83 and p-value = 0.084.

It can therefore be concluded that Fabric 2 is rated as more exciting than Fabric 1 at a significantly high confidence level at 90%. In the Likert scale, a confidence interval estimation at 80% confidence level shows the following:

Mean = -0.632,

Standard Deviation = 1.950,

Standard Error of the Mean = 0.447,

Confidence interval between -1.227 and -0.037, T= -1.41 and p-value = 0.175.

It can therefore be concluded that Fabric 2 is rated as more preferable than Fabric 1 at a confidence level at 80%.

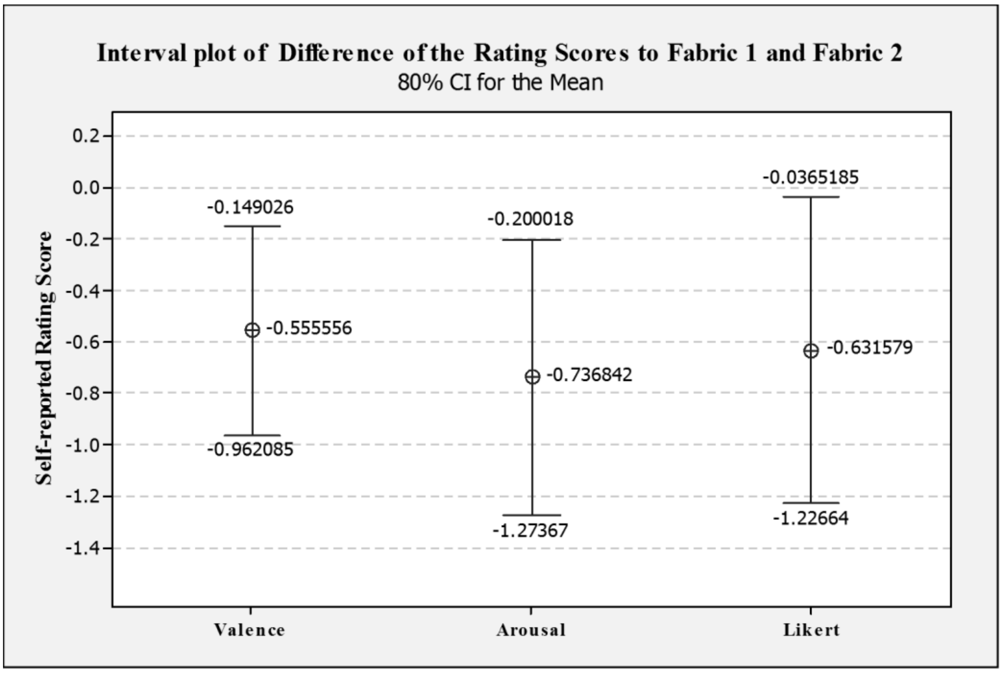


Figure 5-10 People's differences in the subjective rating scores when viewing Fabrics 1 and 2.

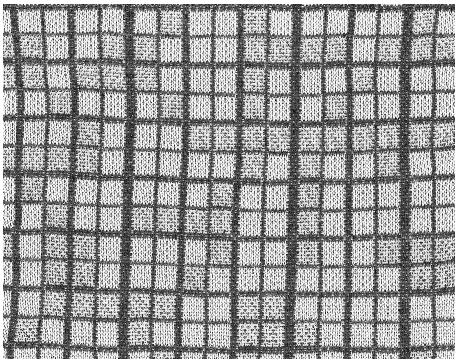
5.3.1.5 Result interpretation summary

There are significant findings in measurable brain responses as well as in people's self-rating of their emotional response to Fabrics 1 and 2. The significant differences observed in current experiment are summarised in Figure 5-11. In the subjective evaluation, the mean of difference of the rating score on the Valence scale is less than zero at 90% confidence level with p-value 0.086, which shows that the rating score of Fabric 2 is significantly higher than the rating score of Fabric 1. Therefore, it shows that people consciously consider Fabric 2 as more pleasant than Fabric 1. In their brain wave response, significant differences were observed in the Gamma frequency power in the frontal, central and parietal regions of the brain. The mean of the difference is over zero at over 80% confidence level, which shows that Fabric 1 triggered higher Gamma frequency power in the frontal, central and parietal regions of the brain compared with Fabric 2. Gamma frequency power response has been found to be larger in response to negative emotional stimulation. The current observation of Gamma power response might infer that Fabric 1 has an unpleasant effect. This result is consistent with the rating score of the valence scale, in which Fabric 1 is less pleasant than Fabric 2. This finding is in agreement with other studies of Gamma power response and emotion [80, 153, 154]. Furthermore, the measurement of people's heart rate response also indicates the same result. Significant difference in people's heart rate change was observed in the initial 3 second response at 95% confidence level, in which people have heart rate acceleration to Fabric 1 and deceleration to Fabric 2. Heart rate acceleration has been found to occur in the defensive response that reduces sensitivity to unpleasant stimuli [2, p429-432]. The current result might infer that Fabric 1 has an unpleasant effect on people's response. It is therefore consistent to conclude that Fabric 2 is more pleasant than Fabric 1. In summary, Fabric 2 has a more pleasant effect than Fabric 1, which is established by analysing people's subjective evaluation, their brain waves and their cardiac reactions.

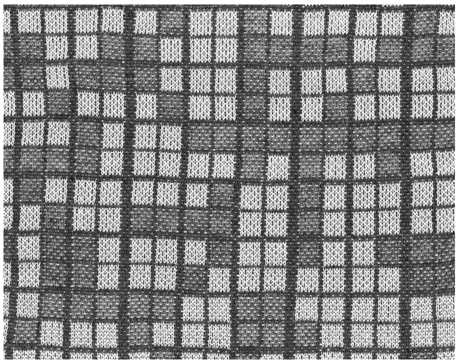
Fabric	Subjective Evaluation			Brain Wave Activity		Cardiac Activity
	SAM Scales		Likert Scale	Frequency Band Powers of the Brain Waves	Frontal Alpha Asymmetry Index	Heart Rate Changes
	Valence Scale (Pleasant – Unpleasant)	Arousal Scale (Exciting – Calm)				
Fabric 1 Vs Fabric 2	Fabric 2 is rated as more pleasant than Fabric 1 at a significantly high confidence level at 90%, p-value 0.086.	Fabric 2 is rated as more exciting than Fabric 1 at a significantly high confidence level at 90%, p-value 0.084.	Fabric 2 is rated as more preferable than Fabric 1 at a confidence level at 80%, p-value 0.175.	• Delta frequency power: Fabric 1 trigged significantly higher Delta power in the frontal region of the brain, which might infer that Fabric 1 has more emotional effect than Fabric 2. • Gamma frequency power: Fabric 1 triggered significantly higher Gamma frequency power in the frontal, central and parietal regions of the brain, which might infer that Fabric 1 has more unpleasant effect on people's emotional response than Fabric 2.	No significant Frontal Alpha Asymmetry Index was found in either Fabric 1 or 2 at 80% confidence level.	People's heart rate responses to Fabrics 1 and 2 is significantly different in the initial 3 seconds at 95% confidence level, in which a heart rate acceleration to Fabric 1 and deceleration to Fabric 2 was recorded. This result might infer that Fabric 1 has an unpleasant effect.

Figure 5-11 Summary of established significant differences in people's emotional responses to the viewing of Fabrics 1 and 2.

5.3.2 Investigating the differences in people's responses to Fabrics 3 and 4



Fabric 3



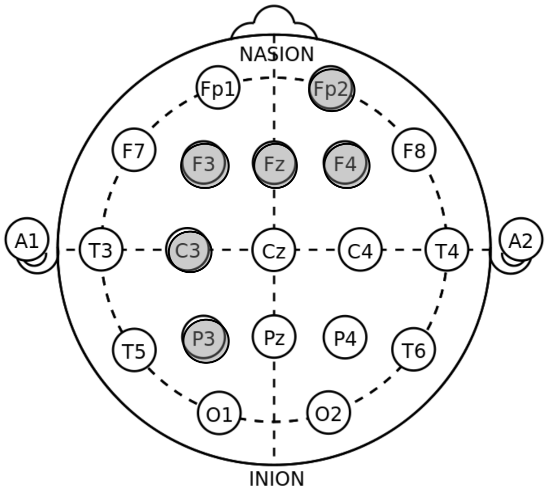
Fabric 4

5.3.2.1 Frequency band power of the EEG

The difference of the 5 frequency band powers of the twenty participants when responding to Fabric 3 and Fabric 4 are reported in Appendices C.14 – C.18. The observed significant differences of each frequency band are reported as follows.

- Delta frequency power

Significant differences in Delta power response were found in 6 electrode channels, as shown in Figure 5-12. Four channels are located in the prefrontal and frontal regions of the brain. They are the Fp2, F3, Fz and F4 channels. In these locations, the mean of the difference is over zero at 93%, 95%, 95% and 90% confidence levels. This result shows that Fabric 3 triggered significantly higher Delta power than Fabric 4 in the prefrontal and frontal regions of the brain. In the C3 and P3 channel locations, the mean of the difference are over zero at 80% confidence level, which shows Fabric 3 also evoked higher Delta power than Fabric 4 in these areas of the brain. The Delta response in the frontal region of the brain has been found to be higher in response to emotional stimuli than neutral stimuli [168]. In the current investigation, the significant difference observed in the frontal region of the brain might infer that Fabric 3 has more emotional effect than Fabric 4. Either positive or negative emotional effect is unclear because it is undefined in the literature.



Variable	N	Mean	StDev	SE Mean	93% CI	T	P
Fp2	20	2.15	4.71	1.05	(0.12, 4.17)	2.04	0.056

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
F3	20	3.23	6.23	1.39	(0.31, 6.15)	2.32	0.032

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
F4	20	3.16	5.66	1.27	(0.51, 5.81)	2.50	0.022

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Fz	20	2.52	5.97	1.34	(0.21, 4.83)	1.89	0.074

Variable	N	Mean	StDev	SE Mean	80% CI	T	P
C3	17	0.699	2.052	0.498	(0.033, 1.364)	1.40	0.180

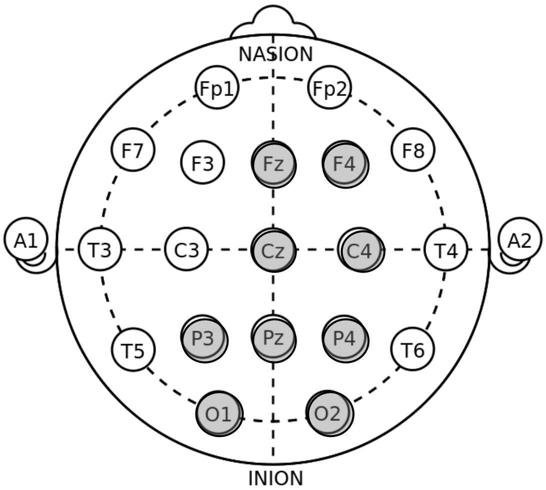
Variable	N	Mean	StDev	SE Mean	80% CI	T	P
P3	20	1.74	5.66	1.27	(0.06, 3.42)	1.37	0.185

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-12 Significant differences of the brain's Delta power, when responding to Fabrics 3 and 4.

- Theta frequency power

Significant differences in Theta power response were found in the Fz and F4 channels located in the frontal region of the brain, in the Cz and C4 channels located in the centre of the brain, in the P3, Pz and P4 channels located over the parietal region of the brain, and in the O1 and O2 channels located over the occipital region of the brain, as shown in Figure 5-13. The mean of the difference in these channels is over zero at the confidence levels over 85%. This result shows that Fabric 3 evoked higher Theta power than Fabric 4 on most regions of the brain. The Theta power in the frontal, parietal and occipital regions of the brain has been found to be increased in response to emotional stimuli; in some studies it has been observed in response to positive stimuli; and the frontal middle Theta power has been found to be positively correlated with the pleasantness emotional effect [150, 151, 169]. In the current investigation, the significant results might infer that Fabric 3 has more emotional effect than Fabric 4, and this emotional effect could be positive and pleasant.



Variable	N	Mean	StDev	SE Mean	95% CI	T	P
P4	20	2.61	5.20	1.16	(0.17, 5.04)	2.24	0.037

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
O2	20	1.915	4.288	0.959	(0.257, 3.572)	2.00	0.060

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Pz	20	2.65	4.87	1.09	(0.37, 4.93)	2.43	0.025

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
O1	20	1.937	3.986	0.891	(0.072, 3.803)	2.17	0.043

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
F4	20	2.12	4.76	1.06	(0.28, 3.96)	1.99	0.061

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
C4	20	2.678	4.455	0.996	(0.593, 4.763)	2.69	0.015

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
Fz	20	1.64	4.89	1.09	(0.00, 3.28)	1.50	0.150

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Cz	20	2.12	4.86	1.09	(0.24, 3.99)	1.95	0.066

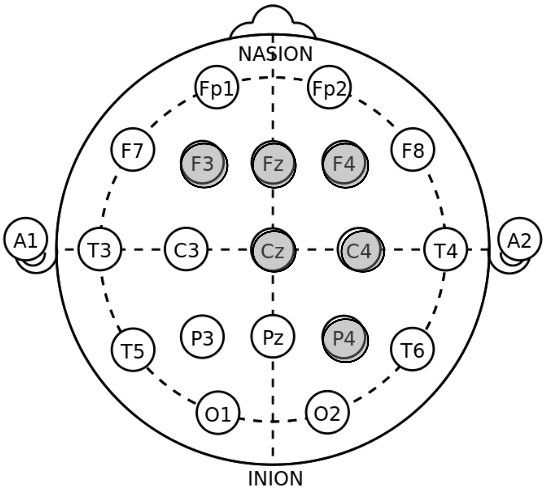
Variable	N	Mean	StDev	SE Mean	90% CI	T	P
P3	20	2.39	5.64	1.26	(0.21, 4.57)	1.89	0.074

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-13 Significant differences of the brain's Theta power, when responding to Fabrics 3 and 4.

- Alpha frequency power

Significant differences in Alpha power response were found in the F3, Fz and F4 channels located in the frontal region of the brain, the Cz and C4 channels location in the central region of the brain, and the P4 channel located in the parietal region of the brain, as shown in Figure 5-14. The mean of the difference in these channels is over zero at confidence levels over 85%. This result shows that Fabric 3 evoked higher Alpha power than Fabric 4 in these locations of the brain. The relation between human emotional process and the Alpha power response in the central or parietal regions of the brain has not been found in literature. Therefore, no inference is made from the current findings in the Cz, C4 and P4 channel locations. The significant difference of Alpha response in the frontal regions of the brain is analysed in the following section on the Frontal Alpha Asymmetry index.



Variable	N	Mean	StDev	SE Mean	85% CI	T	P
P4	20	1.473	4.353	0.973	(0.013, 2.933)	1.51	0.147

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
F3	20	1.094	3.158	0.706	(0.035, 2.154)	1.55	0.138

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
F4	20	1.372	3.261	0.729	(0.111, 2.633)	1.88	0.075

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
C4	20	1.527	4.194	0.938	(0.120, 2.934)	1.63	0.120

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
Fz	20	1.088	2.969	0.664	(0.092, 2.084)	1.64	0.118

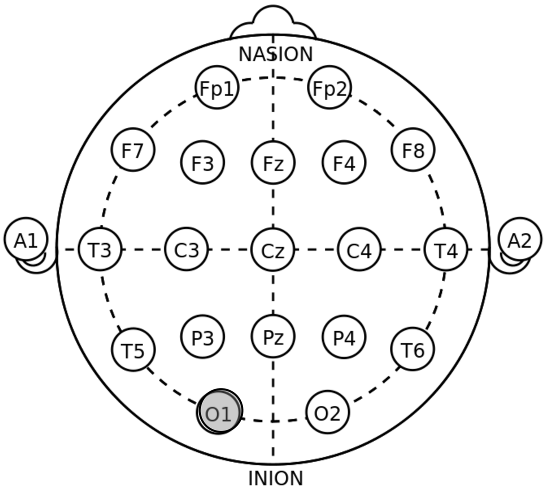
Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Cz	20	0.910	2.338	0.523	(0.006, 1.814)	1.74	0.098

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-14 Significant differences of the brain's Alpha power, when responding to Fabrics 3 and 4.

- Beta frequency power

Significant difference in the Beta power response was only found in the O1 channel located on the left of the occipital region of the brain, as shown in Figure 5-15. The mean of the difference at 90% confidence level is less than zero, which shows that Fabric 3 triggered less Beta power than Fabric 4 in this location of the brain. However, the connection between Beta power response in the occipital lobe of the brain and the human emotional process is undefined in literature. Therefore, no inference is made from the current result.



Variable	N	Mean	StDev	SE Mean	90% CI	T	P
O1	17	-0.486	1.139	0.276	(-0.968, -0.003)	-1.76	0.098

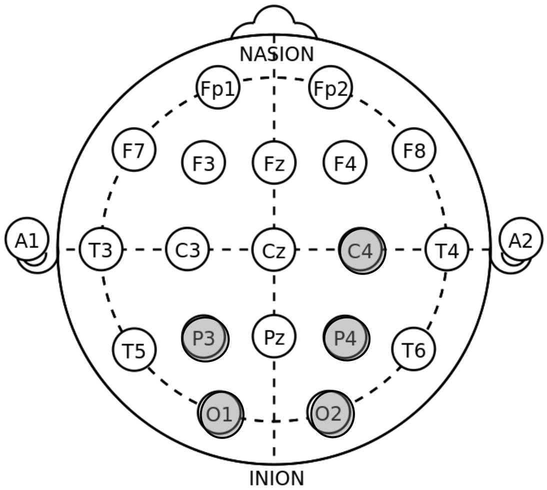
*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-15 Significant differences of the brain's Beta power, when responding to Fabrics 3 and 4.

- Gamma frequency power

Significant differences in the Gamma power response was observed in five channel locations, which are the C4 , P3, P4 O1 and O2 channels, as shown in Figure 5-16. The mean of the difference in the C4, P4, O1 and O2 channel locations is over zero at over 80% confidence level. This result shows that Fabric 3 triggered higher Gamma power than Fabric 4 in the right of the central and parietal regions of the brain, and also over the occipital region of the brain. In the P3 channel location, the mean of the difference at 95% confidence level is less than zero, which shows that Fabric 3 triggered less

Gamma power at the left of the parietal regional of the brain. Gamma power has been found to be larger in response to negative emotional stimulation [80, 153, 154], and the increased Gamma power in the occipital region of the brain has been reported in response to unpleasant stimuli [152]. In the current observation, the significant difference found in the occipital area of the brain might infer that Fabric 3 has an unpleasant effect on people's emotional response. However, there is a different result found between the left and the right of the parietal lobes of the brain. The significant results show that Fabric 4 evoked higher Gamma power response in the left parietal lobe, but lower in the right parietal lobe. A further study is required to clarify the difference.



Variable	N	Mean	StDev	SE Mean	95% CI	T	P
P4	20	0.938	1.657	0.370	(0.163, 1.713)	2.53	0.020

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
O2	20	0.991	2.057	0.460	(0.028, 1.954)	2.15	0.044

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
O1	20	0.560	1.648	0.368	(0.008, 1.113)	1.52	0.145

Variable	N	Mean	StDev	SE Mean	80% CI	T	P
C4	20	0.540	1.679	0.376	(0.041, 1.038)	1.44	0.167

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
P3	15	-0.464	0.796	0.206	(-0.905, -0.024)	-2.26	0.040

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-16 Significant differences of the brain's Gamma power, when responding to Fabrics 3 and 4.

5.3.2.2 The Frontal Alpha Asymmetry index

The Frontal Alpha Asymmetry indices of the twenty participants corresponding to Fabric 3 and 4 are reported in Appendices C.19 – C.20. The confidence intervals of the mean of the Frontal Alpha Asymmetry index of the fabrics at 80% confidence level are presented in Figure 5-17. In the cases of both fabrics, the mean of the Frontal Alpha Asymmetry index is undefined neither positive nor negative, and therefore they have no significance, revealing no population preference in either Fabric 3 or 4.

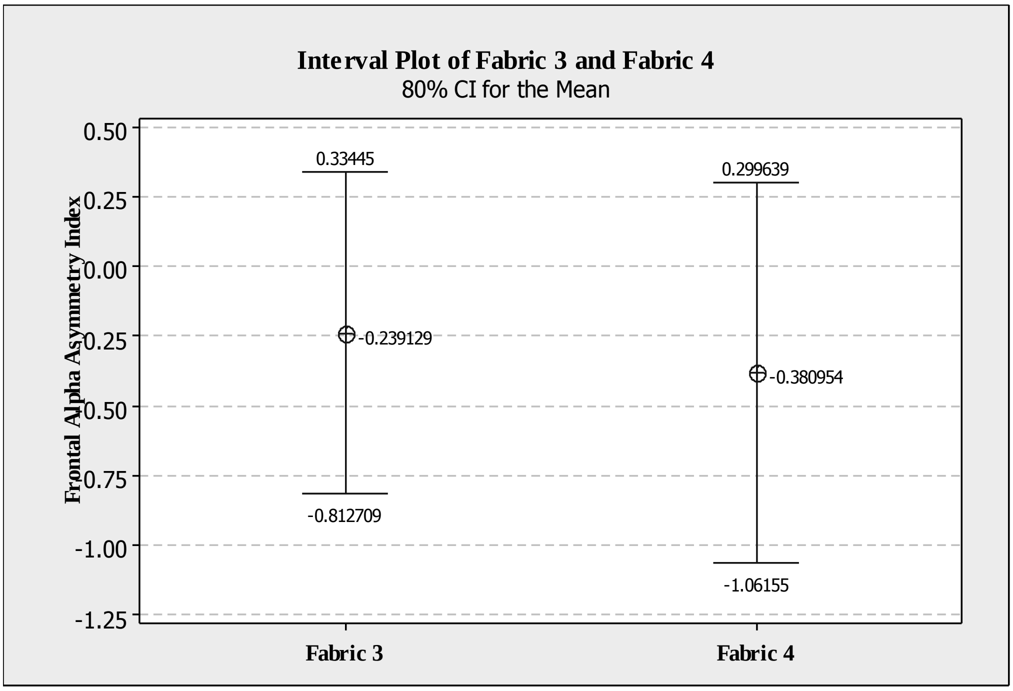


Figure 5-17 The Frontal Alpha Asymmetry index of Fabrics 3 and 4.

5.3.2.3 Heart rate changes

The heart rate changes of the twenty participants in each time window when responding to Fabrics 3 and 4 are reported in Appendices C.21 - C.22. At 80% confidence level, the mean of the heart rate change to Fabric 3 was calcuated and the statistical results are shown in Figure 5-18. The signficant results were observed in the 3rd to 10th time windows. Same result was found at 90% confidence level, in which the mean of the heart rate change is less than zero. This result shows that, from 3rd to 10th second of the fabric viewing, viewers' heart rate response to Fabric 3 is a deceleration compared to the baseline period. In the first two time windows, the mean of the heart rate change is undefined, neither postive nor negative, and therefore it has no signficant result.

At 80% confidence level, the mean of the heart rate change responding to the viewing of Fabric 4 is shown in Figure 5-19. Signficant reuslts were found in the 2nd, 6th, 8th, 9th and 10th time windows. The same result was found at 90% confidence level, in which the mean of the heart rate change is less than zero. This shows that viewers' heart rate response to Fabric 4 was a deceleration in these time windows compared to the baseline heart rate. In other time windows, the mean of the heart rate change is undefined, neither postive nor negative, and therefore they have no signficant result.

The difference of viewers' heart rate change responses between Fabrics 3 and 4 was caculated and the sample data of the twenty participants is reported in Appendix C.23. At 80% confidence level, the mean of the difference of each time window is shown in Figure 5-20. Signficant differences were only observed in the 4th and 5th time windows, in which the mean of the difference was less than zero. However, the significant heart rate change was only found in Fabric 3 as deceleration in these time windows, the heart rate change responding to the viewing of Fabric 4 is undefined, therefore, no conclusion of the comparison is made from the current result.

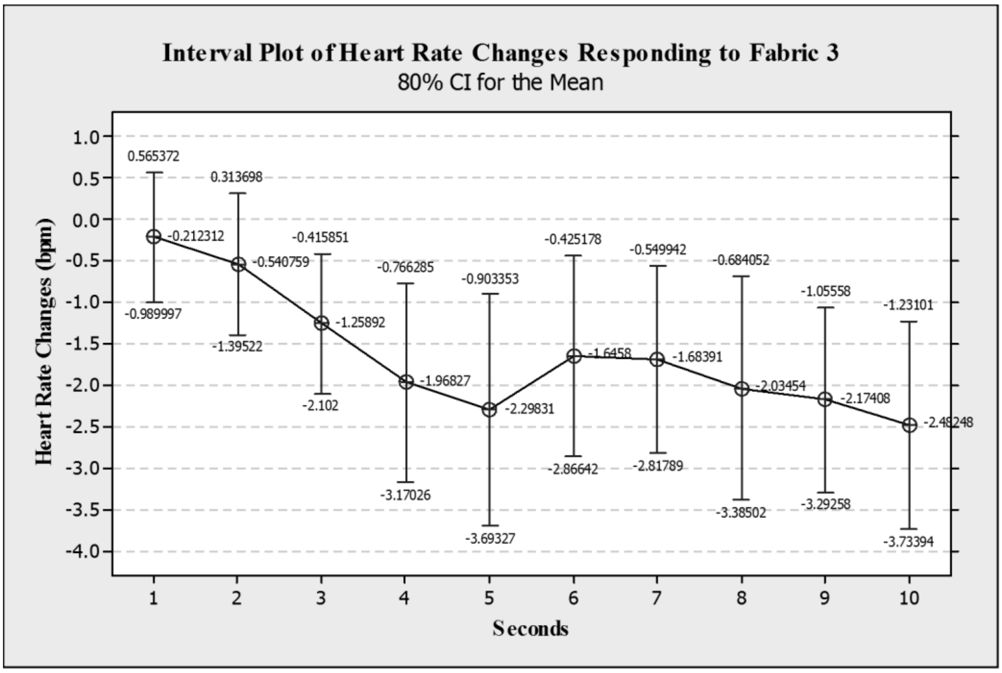


Figure 5-18 People's heart rate changes responding to the viewing of Fabric 3.

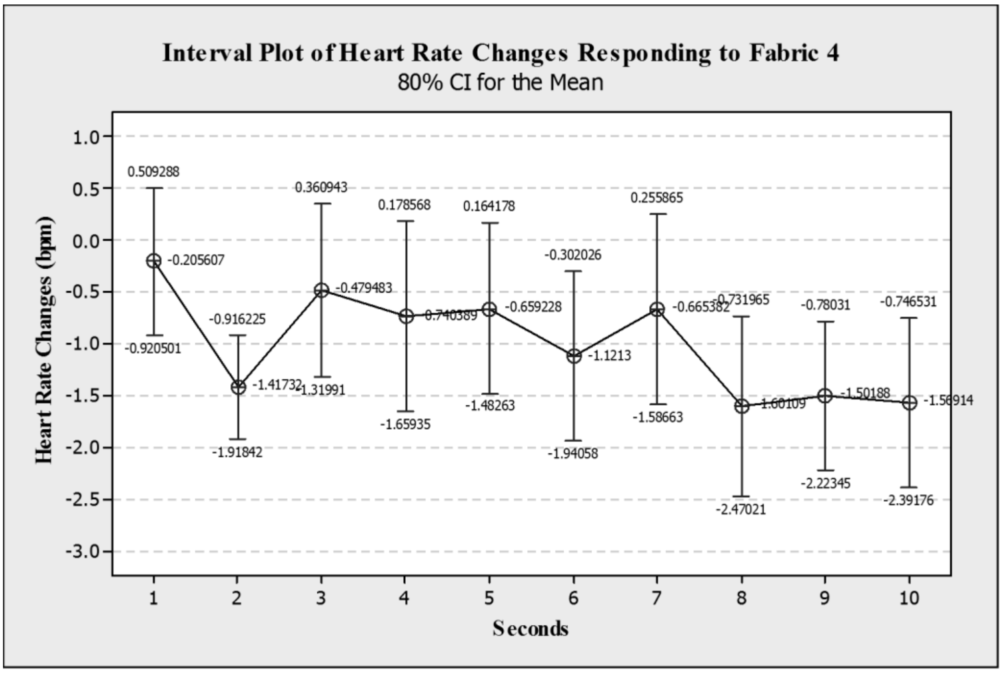


Figure 5-19 People's heart rate changes responding to the viewing of Fabric 4.

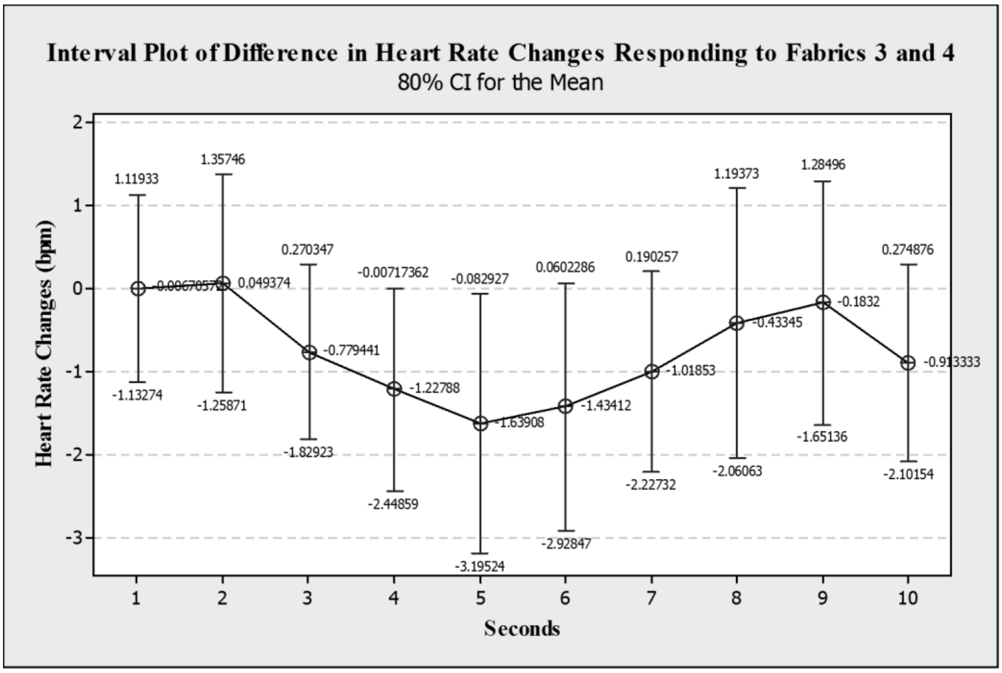


Figure 5-20 Differences of people's heart rate changes when viewing Fabrics 3 and 4.

5.3.2.4 *Subjective analysis*

The rating scores by the twenty participants of the Valence, Arousal and Likert scales to Fabrics 3 and 4 are reported in Appendix C.24. One participant's rating scores on the three scales were removed because they were found to be unsuitably biased. The difference between the rating scores of Fabrics 3 and 4 was calculated on each scale. At 80% confidence level, the mean of the difference are presented in Figure 5-21. A significant difference was only found in the Arousal scale. A confidence interval estimation at 99% confidence level shows the following:

Mean = -1.263,

Standard Deviation = 1.661,

Standard Error of the Mean = 0.381,

Confidence interval between -2.360 and -0.166, T=-3.31 and p-value = 0.004.

It can therefore be concluded that Fabric 4 is rated to have a bigger exciting effect than Fabric 3 at a significantly high confidence level at 99%. In the Valence and Likert scales, the mean of the difference is undefined neither positive nor negative, and therefore it has no significant difference, revealing no difference in people's valence response or preference between Fabrics 3 and 4.

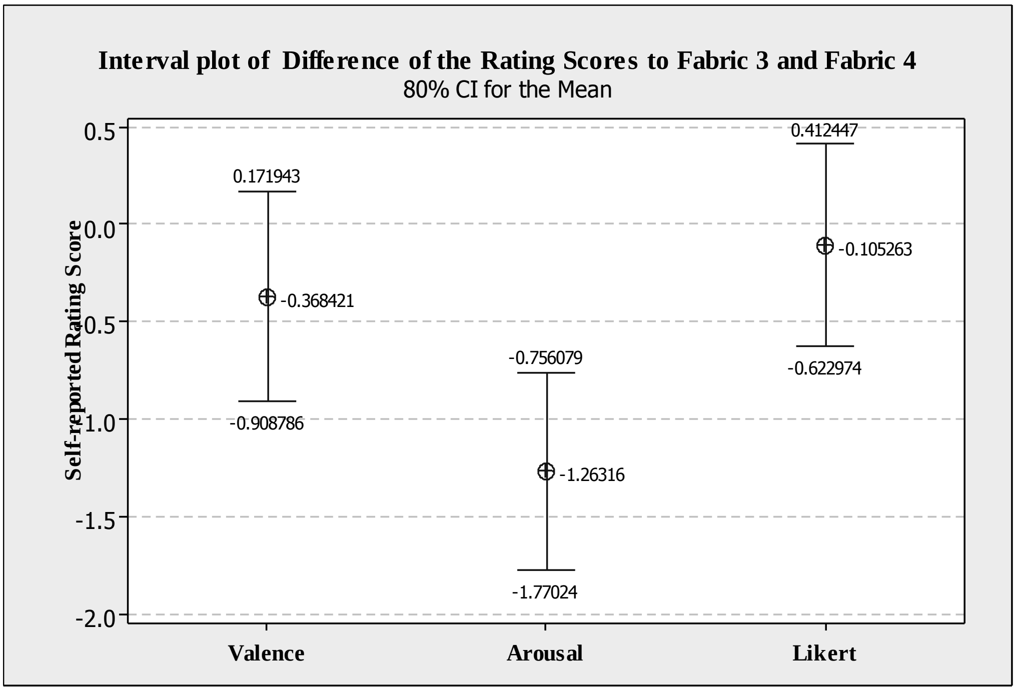


Figure 5-21 *People's difference in the subjective rating scores when viewing Fabrics 3 and 4.*

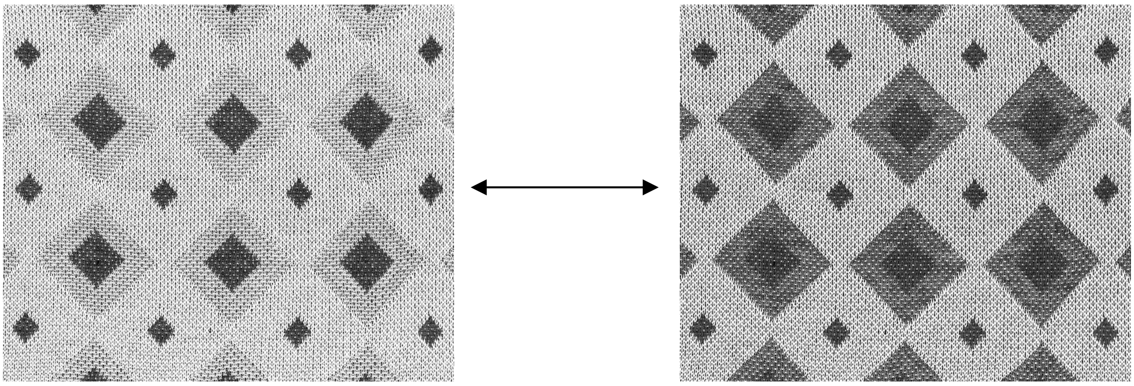
5.3.2.5 Result interpretation summary

Significant results were found in brain response and people's subjective rating of their response to Fabrics 3 and 4. The significant differences observed in the current experiment are summarised in Figure 5-22. The most significant finding is that Fabric 4 has a more exciting effect than Fabric 3 on people's emotional response. In the subjective evaluation, the significant difference was found in the rating score of the Arousal scale. The mean of the difference at 99% confidence level was less than zero, which shows that the rating score of Fabric 4 was significantly higher than the rating score of Fabric 3. This result indicates that people consciously consider that Fabric 4 has more arousal effect such as more exciting than Fabric 3. In their brain wave responses, Fabric 3 triggered significantly higher Theta power in most areas of the brain (frontal, central, parietal and occipital regions). Widespread distribution of Theta response has been observed during drowsiness and states of low-level alertness because of inefficient information processing [2, p69]. Therefore, the current observation shows that people experience less excitement when responding to Fabric 3. Fabric 3 also triggered significantly higher Alpha power in the frontal lobe, central sulcus and parietal lobe of the brain than Fabric 4. The Alpha wave is reversely associated with brain activities. Therefore, Fabric 3 triggers less brain activity than Fabric 4; in other words, Fabric 4 has a higher awakening effect. In summary, Fabric 4 evokes a higher level of excitement in people's emotional response than Fabric 3. This result is established by analysing people's subjective evaluation and their brain wave reactions.

Fabric	Subjective Evaluation			Brain Wave Activity		Cardiac Activity
	SAM Scales		Likert Scale	Frequency Band Powers of the Brain Waves	Frontal Alpha Asymmetry Index	Heart Rate Changes
	Valence Scale (Pleasant – Unpleasant)	Arousal Scale (Exciting – Calm)				
Fabric 3 Vs Fabric 4	No significant difference was found.	Fabric 4 was rated as more exciting than Fabric 3 at 99% confidence level, p-value 0.004.	No significant difference was found.	• Delta frequency power: Fabric 3 triggered significantly higher Delta power than Fabric 4 in the prefrontal and frontal regions of the brain at 90% confidence level, which might infer that Fabric 3 has more emotional effect than Fabric 4. • Theta frequency power: Fabric 3 triggered higher Theta frequency power in most frontal, central, parietal and occipital regions of the brain compared with Fabric 4, which might infer that Fabric 3 has more emotional effect than Fabric 4, and the emotional effect could be positive and pleasant.	No significant result was found in the Frontal Alpha Asymmetry index of either Fabric 3 or 4.	No significant result was found.

Figure 5-22 Summary of established significant differences in people's emotional responses to the viewing of Fabrics 3 and 4.

5.3.3 Investigating the differences in people's responses to Fabrics 5 and 6



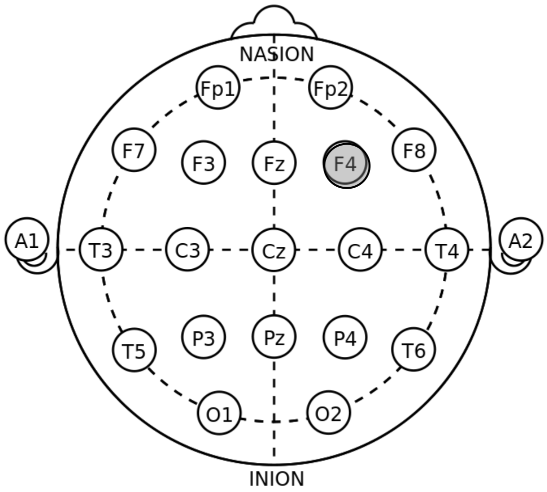
Fabric 5 Fabric 6

5.3.3.1 Frequency band power of the EEG

The differences in the 5 frequency band powers of the twenty participants when responding to Fabric 5 and Fabric 6 are reported in Appendices C.25 – C.29. The observed significant differences of each frequency band are reported as follows.

- Delta frequency power

Significant difference in Delta power response was only found in the F4 channel located at the right of the frontal region of the brain, as shown in Figure 5-23. The mean of the difference at 80% confidence level is over zero, which shows that Fabric 5 triggers higher Delta power than Fabric 6 in this location of the brain. The Delta response in the frontal region of the brain has been found to be higher in response to emotional stimuli than neutral stimuli [168]. The significant difference in the current result might infer that Fabric 5 has more emotional effect than Fabric 6.



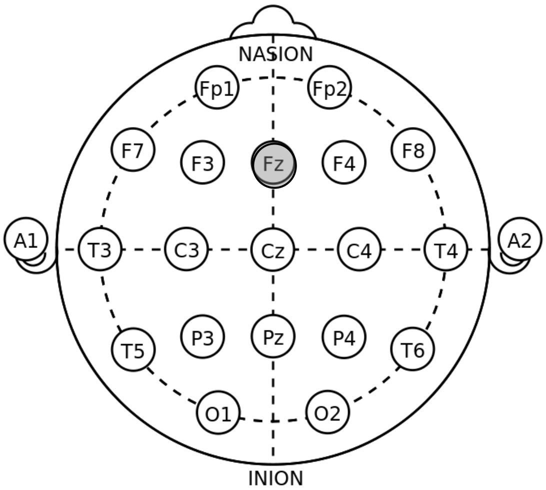
Variable	N	Mean	StDev	SE Mean	80% CI	T	P
F4	20	1.64	5.07	1.13	(0.13, 3.14)	1.45	0.164

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-23 Significant differences of the brain's Delta power, when responding to Fabrics 5 and 6.

- Theta frequency power

Significant difference in Theta power response was only found at the centre of the frontal region of the brain at the Fz channel, as shown in Figure 5-24. The mean of the difference is less than zero at 85% confidence level, which shows that Fabric 5 evokes less Theta power than Fabric 6 in this location of the brain. The Frontal middle Theta power has been found to be positively correlated with subjective rating scores of pleasantness of the emotional experience [151]. The significant difference observed in the current result might infer that Fabric 6 induces a more pleasant effect than Fabric 5.



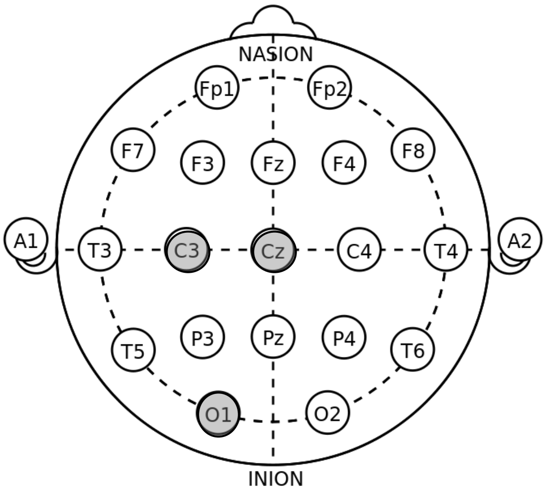
Variable	N	Mean	StDev	SE Mean	85% CI	T	P
Fz	19	-1.544	4.149	0.952	(-2.976, -0.113)	-1.62	0.122

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-24 Significant differences of the brain's Theta power, when responding to Fabrics 5 and 6.

- Alpha frequency power

Significant differences in Alpha power response was observed in the C3, Cz and O1 channels, as shown in Figure 5-25. In the C3 channel location, the mean of the difference is less than zero at 80% confidence level, which shows that Fabric 5 triggered less Alpha power in the left of the Central sulcus of the brain. In the Cz channel location, the mean of the difference is over zero at 85% confidence level, which shows that Fabric 5 triggers higher Alpha power in the centre of the Central sulcus of the brain. In the O1 channel location, the mean of the difference is less than zero at 90% confidence level, which shows that Fabric 5 triggers lower Alpha power in this location of the brain. However, the relationship between the human emotional process and the Alpha power response in the central or occipital regions of the brain has not been found in literature. Therefore, no inference is made from the current results.



Variable	N	Mean	StDev	SE Mean	90% CI	T	P
O1	20	-1.730	4.361	0.975	(-3.417, -0.044)	-1.77	0.092

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
Cz	18	1.021	2.598	0.612	(0.098, 1.945)	1.67	0.114

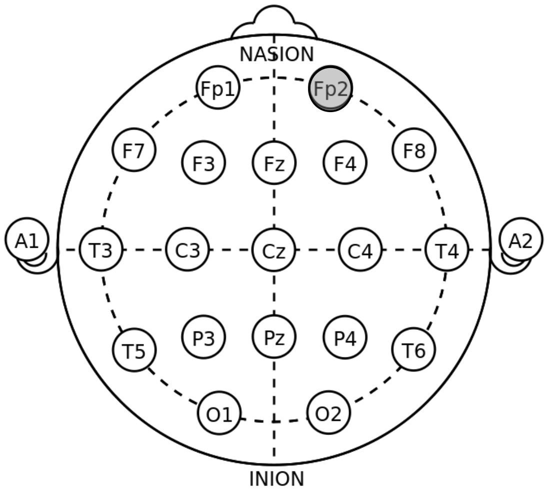
Variable	N	Mean	StDev	SE Mean	80% CI	T	P
C3	20	-0.991	2.975	0.665	(-1.874, -0.107)	-1.49	0.153

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-25 Significant differences of the brain's Alpha power, when responding to Fabrics 5 and 6.

- Beta frequency power

Significant difference in Beta power response was only observed in the Fp2 channel located at the right of the pre-frontal lobe of the brain, as shown in Figure 5-26. The mean of the difference is over zero at 95% confidence level, which shows that Fabric 5 evokes higher Beta frequency power in this location of the brain than Fabric 6. The Beta power in the frontal region of the brain has been found to be greater in response to negative stimuli compared with the response to positive stimuli [79]. Therefore, significant difference observed in the current result might infer that Fabric 5 has more negative effect in people's emotional response compared with Fabric 6.



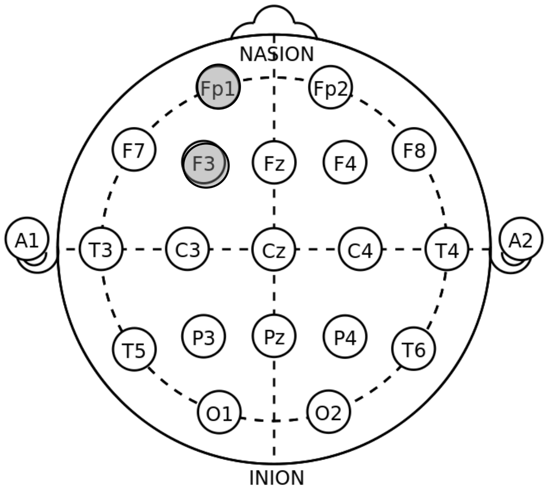
Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Fp2	20	0.869	1.607	0.359	(0.116, 1.621)	2.42	0.026

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-26 Significant differences of the brain's Beta power, when responding to Fabrics 5 and 6.

- Gamma frequency power

Significant differences in Gamma power response were found in the Fp1 and F3 channels, as shown in Figure 5-27. The mean of the difference in both channel locations are over zero at 90% and 95% confidence levels. This result shows that Fabric 5 evokes significantly higher Gamma power in the left of the prefrontal and frontal regions of the brain. Gamma power has been reported to be larger in response to negative unpleasant stimulation [80, 153, 154]. Therefore, the significant differences observed in the current results might infer that Fabric 5 has an unpleasant effect on people's emotional response compared with Fabric 6.



Variable	N	Mean	StDev	SE Mean	95% CI	T	P
F3	19	0.971	1.202	0.276	(0.392, 1.551)	3.52	0.002

Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Fp1	20	0.721	1.666	0.372	(0.077, 1.365)	1.94	0.068

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-27 Significant differences of the brain's Gamma power, when responding to Fabrics 5 and 6.

5.3.3.2 The Frontal Alpha Asymmetry index

The Frontal Alpha Asymmetry indices of the twenty participants, corresponding to Fabrics 5 and 6 are reported in Appendices C.30 – C.31. The mean of the population of the index to each fabric stimulus was estimated and the results are presented in Figure 5-28. A significant mean of the index of Fabric 5 has been found. A confidence interval estimation with 85% confidence level shows the following:

Mean = 0.705,

Standard Deviation = 1.963,

Standard Error of the Mean = 0.439,

Confidence intervals between 0.047 and 1.364.

The interval of the mean is over zero, which shows that the mean of the Frontal Alpha Asymmetry index at 80% confidence level is a positive value. It is therefore established that the viewer's left hemisphere is dominant since the right frontal hemisphere has a higher Alpha power. According to the frontal EEG asymmetry theory, the left dominance of the brain activation reflects an approach oriented response, revealing that people have significant positive preference for Fabric 5. However, in the case of Fabric 6, the mean of the Frontal Alpha Asymmetry index is undefined, neither positive nor negative, and therefore it has no significance, revealing no population approach/withdrawal emotion to Fabric 6.

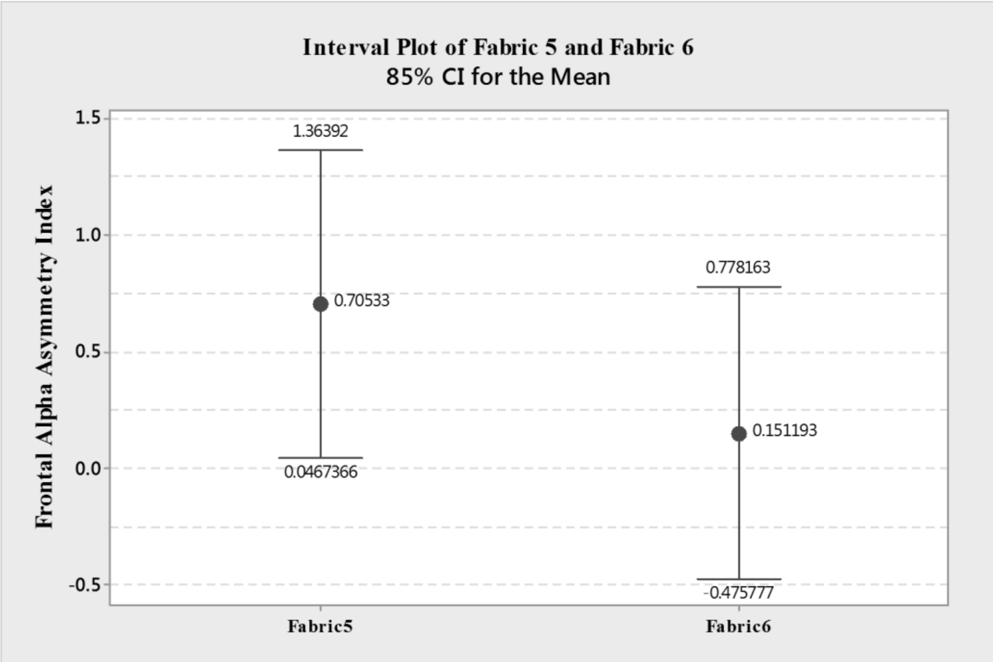


Figure 5-28 The Frontal Alpha Asymmetry index of Fabrics 5 and 6.

5.3.3.3 Heart rate changes

The heart rate changes of the twenty participants in each time window when responding to Fabrics 5 and 6 are reported in Appendices C.32 - C.33. The mean of the heart rate change to Fabric 5 was calculated and the statistical results are shown in Figure 5-29. The signficant heart rate changes at 80% confidence level were observed in the 1st and 8th time windows. The mean of the heart rate change in the 1st time window is over zero, which shows that the viewers' initial 1st second heart rate response to Fabric 5 is an acceleration compared to the baseline period. The mean of the heart rate change in the 8th time window is less than zero, which shows that the viewers' heart rate response at this time window is a deceleration compared to the baseline period. In other time windows, the mean of the heart rate change is undefined, neither postive nor negative, and therefore they have no signficant result.

The mean of the heart rate change responding to the viewing of Fabric 6 is shown in Figure 5-30. At 80% confidence level, signficant results were found in the 3rd, 4th, 6th and 10th time windows. The mean of the heart rate change in these time windows is less than zero, which shows that viewers' heart rate response in these time windows was a deceleration compared to the baseline heart rate. In other time windows, the mean of the heart rate change is undefined, neither postive nor negative, and therefore they have no signficant result.

The difference of viewers' heart rate change responses between Fabrics 5 and 6 was calculated and the sample data of the twenty participants is reported in Appendix C.34. At 80% confidence level, the mean of the difference of each time window is shown in Figure 5-31. Signficant results were observed in the intial 4 seconds of heart rate response, in which the mean of the difference is over zero. However, in this period, signficant heart rate change was not observed in both fabric stimulations at the same time window, which means the viewers' heart rate responses to both fabric stimulations are undefined at the same time, and therefore, the comparison of the heart rate changes in between Fabrics 5 and 6 is inconclusive.

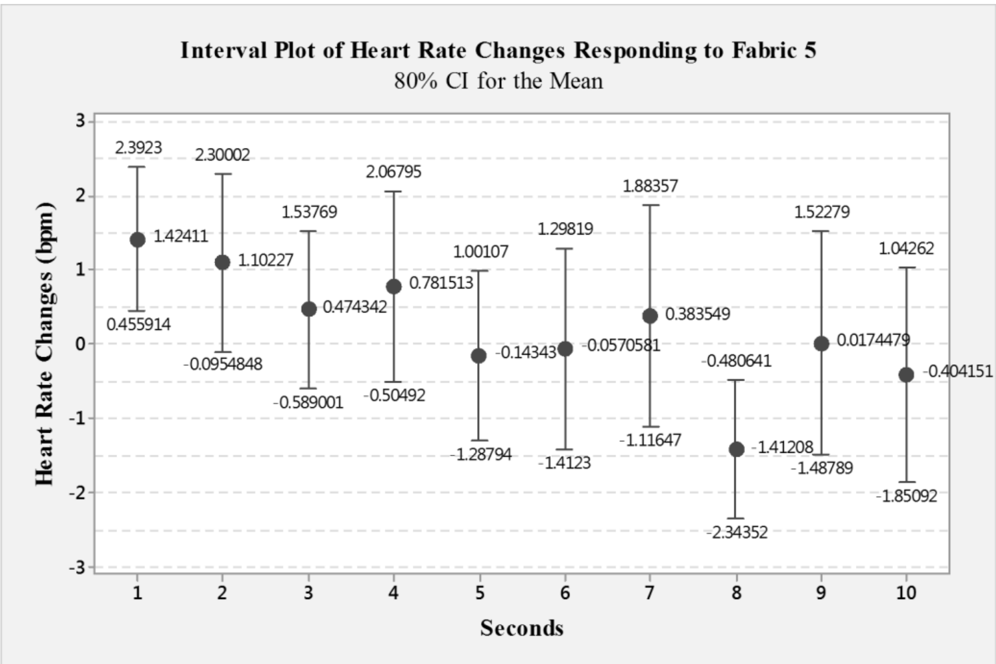


Figure 5-29 People's heart rate changes responding to the viewing of Fabric 5.

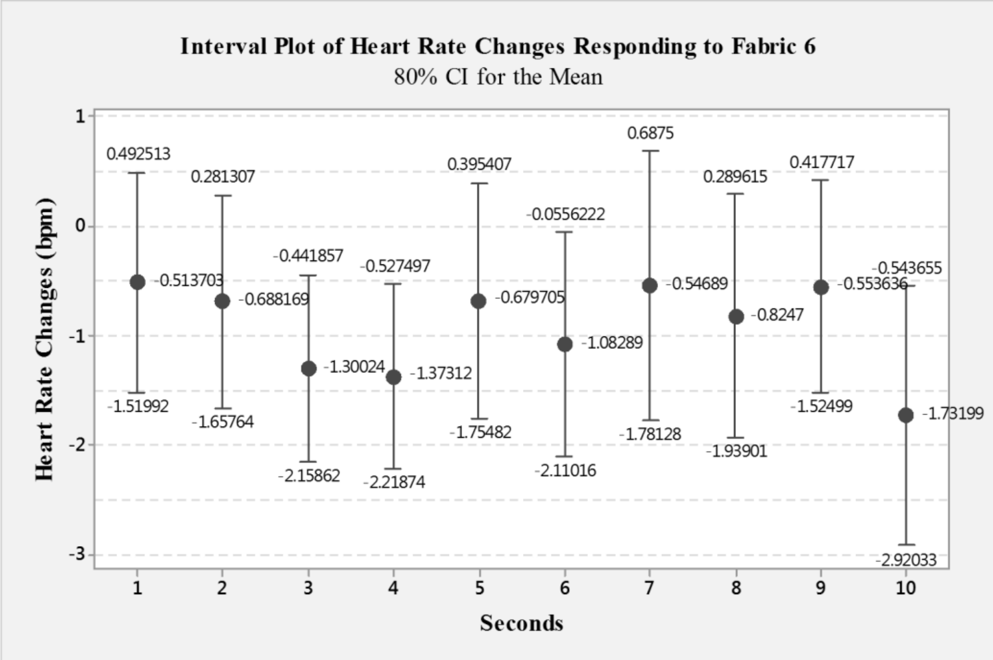


Figure 5-30 People's heart rate changes responding to the viewing of Fabric 6.

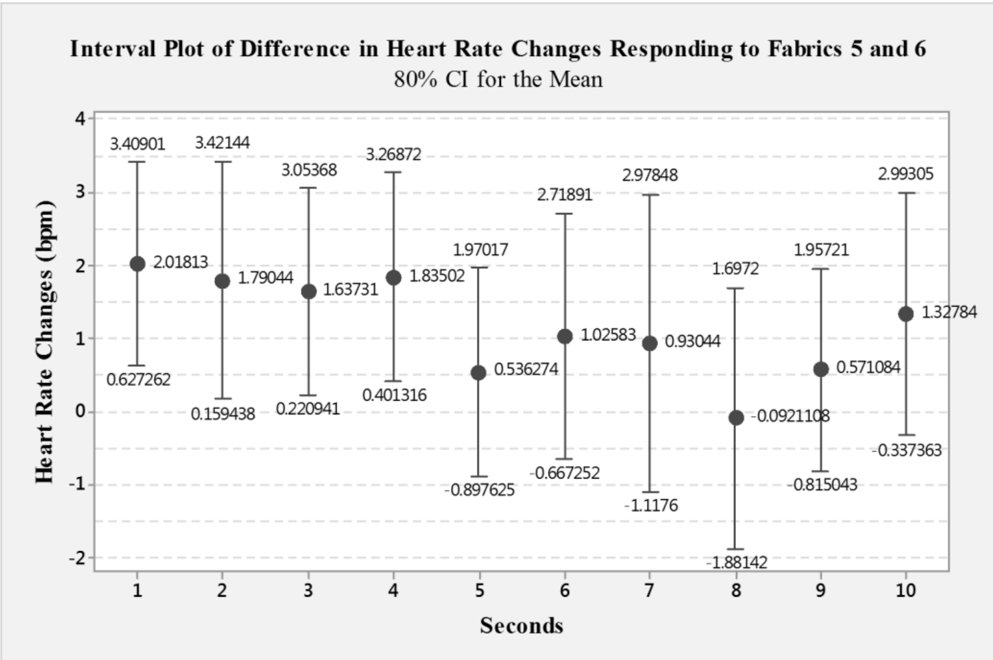


Figure 5-31 Differences of people's heart rate changes when viewing Fabrics 5 and 6.

5.3.3.4 Subjective analysis

The rating scores by the twenty participants of the Valence, Arousal and Likert scales to Fabrics 5 and 6 are reported in Appendix C.35. One participant's rating scores on the three scales were removed because they were found to be unsuitably biased. The difference between the rating scores of Fabrics 5 and 6 was calculated on each scale. At 80% confidence level, the mean of the differences is presented in Figure 5-32. Significant differences were found in the Valence, Arousal and Likert scales. In the Valence scale, a confidence interval estimation at 95% confidence level shows the following:

Mean = -0.947,

Standard Deviation = 1.900,

Standard Error of the Mean = 0.436,

Confidence interval between -1.863 and -0.032, T=-2.17 and p-value = 0.043.

It can therefore be concluded that Fabric 6 is rated as more pleasant than Fabric 5 at a significantly high confidence level at 95%. In the Arousal scale, a confidence interval estimation at 90% confidence level shows the following:

Mean = -0.947,

Standard Deviation = 2.172,

Standard Error of the Mean = 0.498,

Confidence interval between -1.812 and -0.083, T=-1.90 and p-value = 0.073.

It can therefore be concluded that Fabric 6 is rated to have a greater exciting effect than Fabric 5 at a significantly high confidence level at 90%. In the Likert scale, a confidence interval estimation at 86% confidence level shows the following:

Mean = -0.632,

Standard Deviation = 1.770,

Standard Error of the Mean = 0.406,

Confidence interval between -1.259 and -0.004, T=-1.55 and p-value = 0.137.

It can therefore be concluded that Fabric 6 is rated to have more preference from the viewers than Fabric 5 at a significant confidence level at 86%.

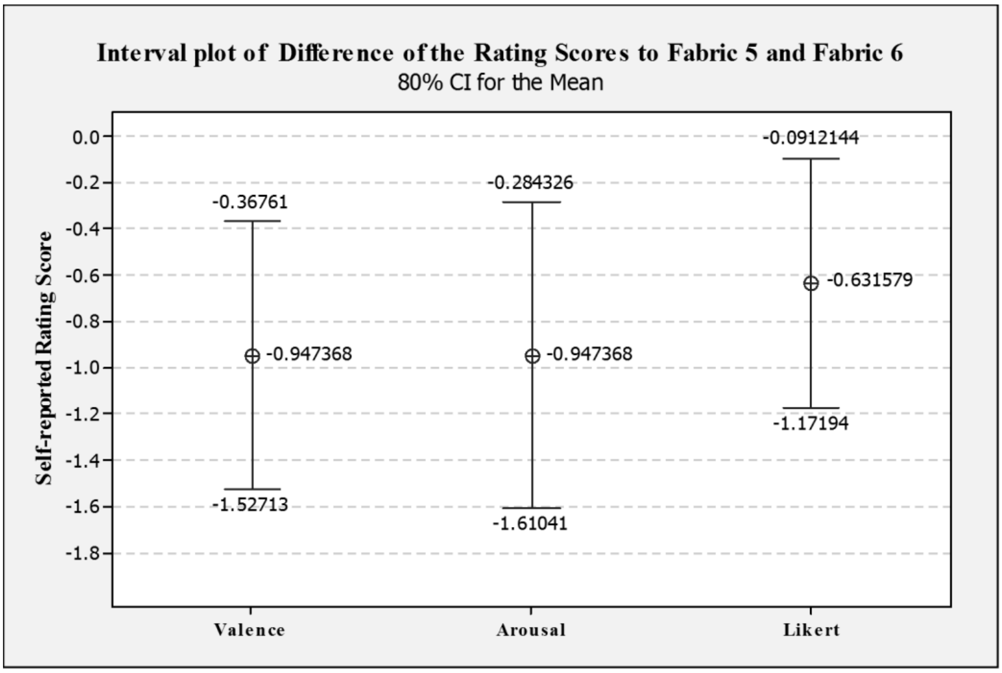


Figure 5-32 People's difference in the subjective rating scores when viewing Fabrics 5 and 6.

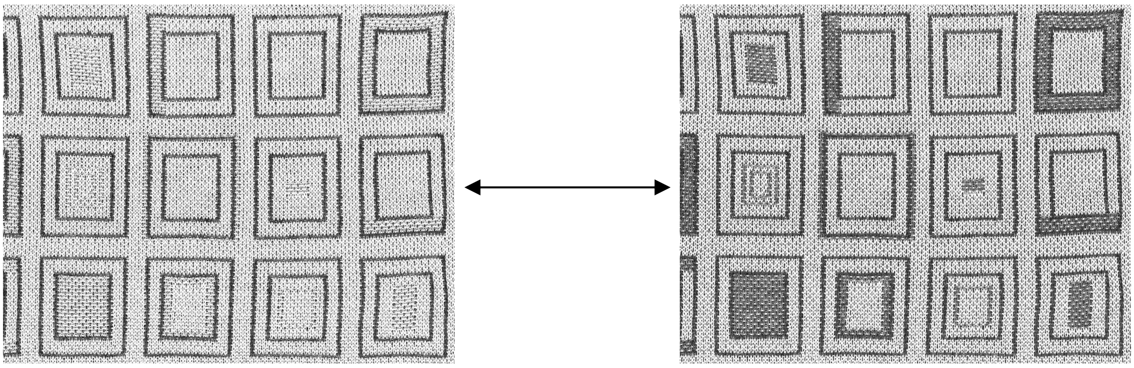
5.3.3.5 Result interpretation summary

Significant results were found in people's subjective evaluation and brain wave responses to the viewing of Fabrics 5 and 6. The significant differences in people's responses observed in the current experiment are summarised in Figure 5-33. The most significant finding is that Fabric 6 has a more pleasant effect than Fabric 5. In the subjective evaluation, significant difference was observed in the rating score of the Valence scale. The mean of the difference at 95% confidence level with p-value 0.043 is less than zero, which shows that the rating score of Fabric 6 is significantly higher than that of Fabric 5. It indicates that people consciously consider Fabric 6 as more pleasant than Fabric 5. In their brain wave response, significant difference was observed in the Theta frequency power response, in which Fabric 6 evoked higher power than Fabric 5 in the middle frontal region of the brain at 85% confidence level with p-value 0.122. The frontal midline Theta power response has been found to be positively correlated with the pleasantness of the emotional experience. Therefore, the current observation shows that Fabric 6 has a more pleasant effect than Fabric 5, which is consistent with the results of subjective evaluation. This finding is in agreement with a similar study of the frontal midline Theta power and emotional response [77]. Significant difference was also found in the Beta frequency power of the brain waves, in which Fabric 5 evoked significantly higher Beta frequency power in the right prefrontal region of the brain at 95% confident level with p-value 0.026. The Beta power in the frontal region of the brain has been found to be greater in response to negative emotional stimuli compared with the response to positive stimuli [79]. Therefore, the current result might indicate that Fabric 5 has a negative effect on people's response. Finally, significant difference was found in the Gamma frequency power response, in which Fabric 5 evokes significantly higher Gamma power in the left pre-frontal and frontal regions of the brain at over 90% confidence level. Gamma power has been reported to be larger in response to unpleasant stimulation [80, 153, 154]. Therefore, the current observation might infer that Fabric 5 has an unpleasant effect on people's responses. Hence, Fabric 6 has a more pleasant effect than Fabric 5. In summary, Fabric 6 influences a more pleasant effect in people's emotional response than Fabric 5, which is established by the results of people's subjective evaluation and their brain wave analyses.

Fabric	Subjective Evaluation			Brain Wave Activity		Cardiac Activity
	SAM Scales		Likert Scale	Frequency Band Powers of the Brain Waves	Frontal Alpha Asymmetry Index	Heart Rate Changes
	Valence Scale (Pleasant – Unpleasant)	Arousal Scale (Exciting – Calm)				
Fabric 5 Vs Fabric 6	Fabric 6 was rated as more pleasant than Fabric 5 at 95% confidence level, p-value 0.043.	Fabric 6 was rated as more exciting than Fabric 5 at 90% confidence level, p-value 0.073.	Fabric 6 was rated as more preferable than Fabric 5 at 86% confidence level, p-value 0.137.	• Delta frequency power: Fabric 5 triggers higher Delta power than Fabric 6 in the right frontal region of the brain at 80% confidence level, which might infer that Fabric 5 has more emotional effect than Fabric 6. • Theta frequency power: Fabric 5 evokes less Theta power than Fabric 6 in the middle frontal region of the brain at 85% confidence level, which might infer that Fabric 6 has a more pleasant effect than Fabric 5. • Beta frequency power: Fabric 5 evokes higher Beta frequency power in the right pre-frontal region of the brain at 95% confidence level, which might infer that Fabric 5 has a more negative effect in people's emotional response. • Gamma frequency power: Fabric 5 evokes significantly higher Gamma power in the left prefrontal region of the brain at 90% confidence level and in the left frontal region of the brain at 95% confidence level, which might infer that Fabric 5 has an unpleasant effect on people's emotional response.	At 85% confidence level, the mean of the index value of Fabric 5, which shows that people have an approach-related emotional experience when responding to Fabric 5. No significant result was found in Fabric 6.	No significant difference was found.

Figure 5-33 Summary of established significant differences in people's emotional responses to viewing of Fabrics 5 and 6.

5.3.4 Investigating the differences in people's responses to Fabrics 7 and 8



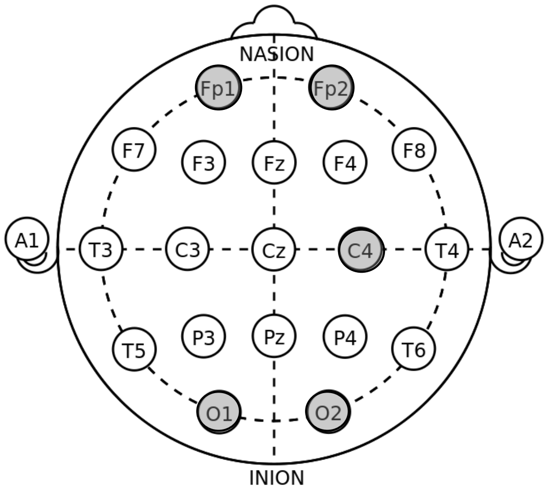
Fabric 7 Fabric 8

5.3.4.1 Frequency band power of the EEG

The differences of the 5 frequency band powers of the twenty participants when responding to Fabric 7 and Fabric 8 are reported in Appendices C.36 – C.40. The observed significant differences of each frequency band are reported as follows.

- Delta frequency power

Significant differences in Delta power response were found in 5 channel locations, as shown in Figure 5-34. They are the Fp1 and Fp2 channels located in the pre-frontal region of the brain, the C4 channel located to the right of the central sulcus of the brain, and the O1 and O2 channels over the occipital region of the brain. The mean of the differences in these locations is less than zero at 80% and 85% confidence levels. This result shows that Fabric 7 evoked significantly less Delta power than Fabric 8 in these regions of the brain. The increased Delta power response in the frontal and occipital regions of the brain has been found in the viewing of emotional stimuli compared with the viewing of neutral stimuli [168, 169]. In the current investigation, the significant differences found in the prefrontal and occipital regions of the brain might infer that Fabric 8 has more emotional effect than Fabric 7.



Variable	N	Mean	StDev	SE Mean	80% CI	T	P
Fp1	20	-2.81	8.85	1.98	(-5.44, -0.19)	-1.42	0.171

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
Fp2	20	-3.01	8.63	1.93	(-5.91, -0.12)	-1.56	0.135

Variable	N	Mean	StDev	SE Mean	80% CI	T	P
O2	20	-2.02	6.55	1.46	(-3.96, -0.08)	-1.38	0.184

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
O1	20	-2.04	6.03	1.35	(-4.06, -0.01)	-1.51	0.147

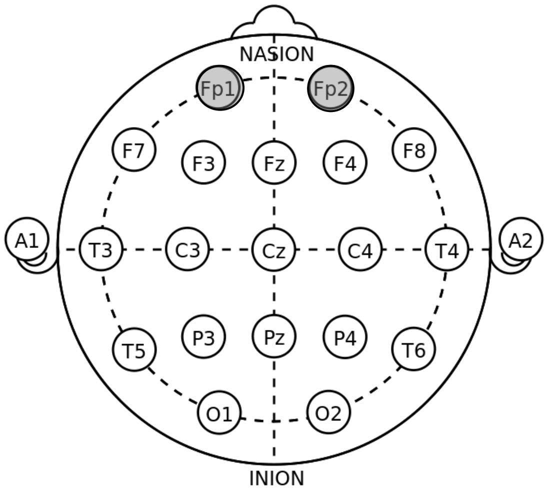
Variable	N	Mean	StDev	SE Mean	85% CI	T	P
C4	20	-1.67	4.72	1.05	(-3.26, -0.09)	-1.59	0.129

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-34 Significant differences of the brain's Delta power, when responding to Fabrics 7 and 8.

- Theta frequency power

Significant differences in Theta power response were found in the Fp1 and Fp2 channels located in the pre-frontal region of the brain, as shown in Figure 5-35. The mean of the differences in these channel locations is less than zero at 90% confidence level. This result shows that Fabric 7 triggers lower Theta power than Fabric 8 in the prefrontal area of the brain. The increased Theta power in the frontal region of the brain has been found in association with emotional facial expression compared with neutral expression [150]. Therefore, the significant difference observed in the current result might infer that Fabric 8 has more emotional effect than Fabric 7.



Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Fp2	20	-2.18	5.47	1.22	(-4.30, -0.07)	-1.79	0.090

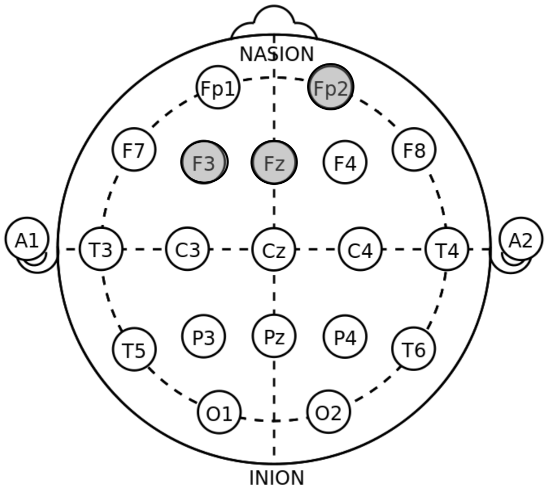
Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Fp1	20	-2.37	6.05	1.35	(-4.70, -0.03)	-1.75	0.096

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-35 Significant differences of the brain's Theta power, when responding to Fabrics 7 and 8.

- Alpha frequency power

Significant differences in Alpha power response were found in the Fp2, F3 and Fz channel locations, as shown in Figure 5-36. The mean of the differences in these locations are less than zero at 95%, 85% and 80% confidence levels, which shows that Fabric 7 triggered lower Alpha power than Fabric 8 at the right of the pre-frontal region of the brain and at the centre and the left area of the frontal region of the brain. In literature, the Alpha power response to emotional process mainly focuses on the frontal EEG asymmetry, the current observation is analysed in the following section of the Frontal Alpha Asymmetry index.



Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Fp2	19	-1.305	2.538	0.582	(-2.529, -0.082)	-2.24	0.038

Variable	N	Mean	StDev	SE Mean	85% CI	T	P
F3	20	-1.107	3.100	0.693	(-2.147, -0.067)	-1.60	0.127

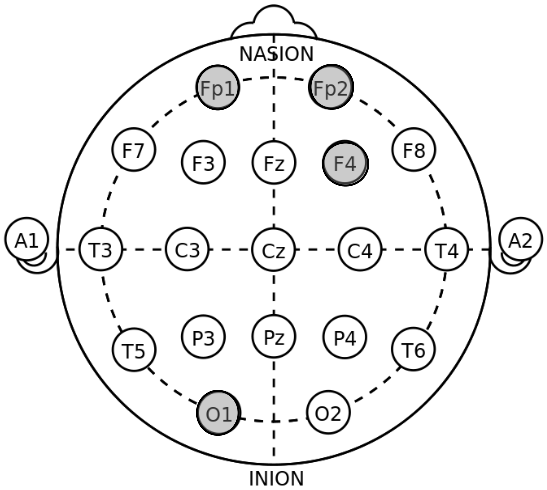
Variable	N	Mean	StDev	SE Mean	80% CI	T	P
Fz	20	-1.219	4.042	0.904	(-2.419, -0.019)	-1.35	0.193

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-36 Significant differences of the brain's Alpha power, when responding to Fabrics 7 and 8.

- Beta frequency power

Significant differences in Beta power response were observed in the Fp1, Fp2, F4 and O1 channel locations, as shown in Figure 5-37. In the Fp1 channel location, the mean of the difference is over zero at 90% confidence level. However, in the Fp2 channel location, the mean of the difference is less zero at 95% confidence level. These results show that Fabric 7 triggered significantly higher Beta power in the left pre-frontal region of the brain, but less Beta power in the right pre-frontal region of the brain when comparing to Fabric 8. In the F4 channel location, the mean of the difference is less than zero at 95% confidence level, which shows that Fabric 7 evoked less Beta power in the right frontal region of the brain than Fabric 8. The Beta power in the frontal area of the brain has been found to be larger in response to unpleasant stimuli compared with neutral stimuli [79]. According to the significant differences observed in the right pre-frontal and frontal areas (Fp2 and F4 channels) of the brain, Fabric 8 might have an unpleasant effect on people's emotional response compared with Fabric 7. However, Fabric 7 evokes higher Beta power response than Fabric 8 in the left pre-frontal region of the brain, which might infer an opposed result. Further investigation of this result is required. In the O1 channel location, the mean of the difference at 95% confidence level is less than zero, which shows that Fabric 7 triggers lower Beta power in the left occipital region of the brain. However, the connection between Beta power response in occipital region of the brain and human emotional response is undefined in literature. Therefore, no inference is made from the current result.



Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Fp2	20	-0.951	1.834	0.410	(-1.809, -0.093)	-2.32	0.032

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
O1	18	-1.136	0.919	0.217	(-1.593, -0.680)	-5.25	0.000

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
F4	17	-1.141	0.903	0.219	(-1.605, -0.677)	-5.21	0.000

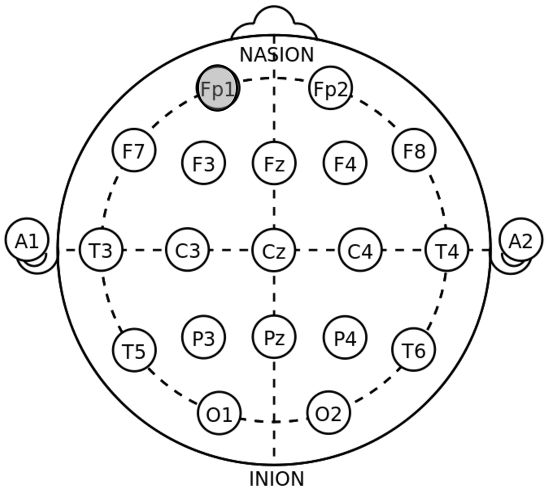
Variable	N	Mean	StDev	SE Mean	90% CI	T	P
Fp1	17	0.515	1.041	0.253	(0.074, 0.956)	2.04	0.058

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-37 Significant differences of the brain's Beta power, when responding to Fabrics 7 and 8.

- Gamma frequency power

Significant difference in Gamma power response was only observed in the Fp1 channel located at the left of the pre-frontal region of the brain, as shown in Figure 5-38. The mean of the differences at 95% confidence level is over zero, which shows that Fabric 7 triggers significantly higher Gamma power than Fabric 8 at the left pre-frontal area of the brain. Increased Gamma power has been found in response to negative emotional stimulation [80, 153, 154]. The current result might infer that Fabric 7 has a unpleasant negative effect on people's emotional response compared with Fabric 8.



Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Fp1	20	0.839	1.727	0.386	(0.031, 1.647)	2.17	0.043

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-38 Significant differences of the brain's Gamma power, when responding to Fabrics 7 and 8.

5.3.4.2 The Frontal Alpha Asymmetry index

The Frontal Alpha Asymmetry indices of the twenty participants corresponding to Fabric 7 and 8 are reported in Appendices C.41 – C.42. The confidence intervals of the mean of the Frontal Alpha Asymmetry index of the fabrics at 80% confidence level are presented in Figure 5-39. In the cases of both fabrics, the mean of the Frontal Alpha Asymmetry index is undefined neither positive nor negative, and therefore they have no significance, revealing no population approach/withdrawal emotion to either Fabric 7 or Fabric 8.

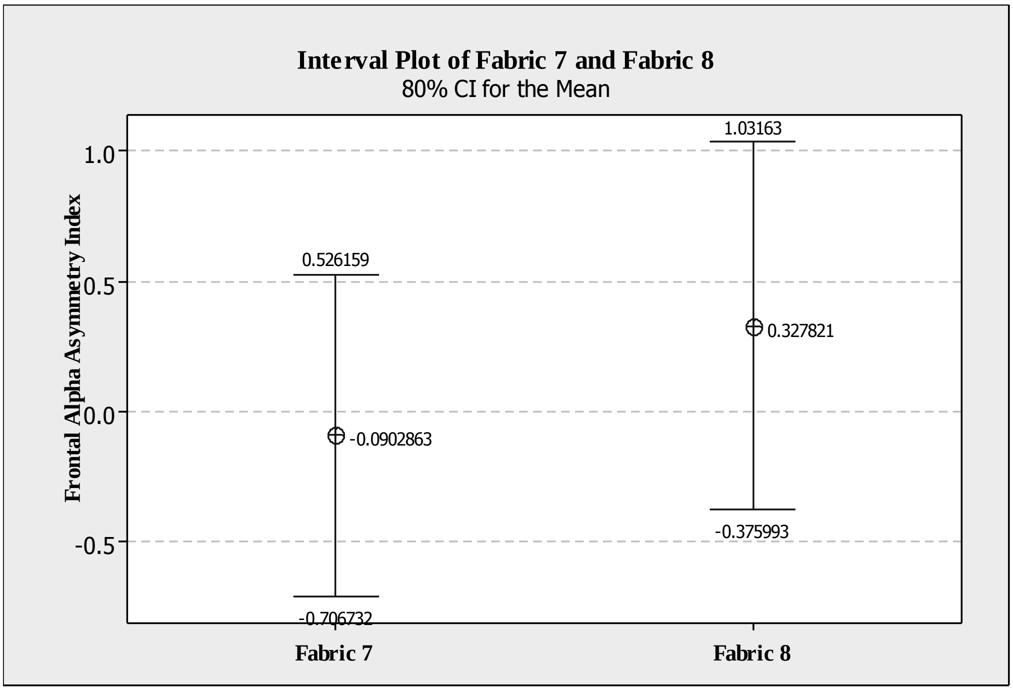


Figure 5-39 The Frontal Alpha Asymmetry index of Fabrics 7 and 8.

5.3.4.3 Heart rate changes

The heart rate changes of the twenty participants in each time window when responding to Fabrics 7 and 8 are reported in Appendices C.43 - C.44. The mean of the heart rate changes to Fabric 7 were calculated and statistical results are shown in Figure 5-40. The significant heart rate changes were observed in the 3rd to 10th time windows, in which the mean of the heart rate changes at 80% confidence level is less than zero. This result shows that viewers' heart rate change from the 3rd to 10th second after the fabric presentation is a deceleration compared to the baseline period. In the initial 2 second response, the mean of the heart rate change is undefined, neither positive nor negative, and therefore has no significant result.

The mean of the heart rate changes responding to the viewing of Fabric 8 is shown in Figure 5-41. Significant results were observed in the whole viewing period except the 3rd, 6th and 10th seconds. The mean of the significant heart rate change at 80% confidence level is less than zero, which shows that the viewers' heart rate change is a deceleration compared to the baseline heart rate. In the 3rd, 6th and 10th time windows, the mean of the heart rate change is undefined, neither positive nor negative, and therefore has no significant result.

The differences of viewers' heart rate change responses between Fabrics 7 and 8 was calcuated and the sample data of the twenty participants are reported in Appendix C.45. At 80% confidence level, the mean of the difference of each time window is presented in Figure 5-42. Signficant results were observed in the 1st, 3rd, 4th, 6th, 7th, and 10th time windows. However, only in the 4th and 7th time windows were significant heart rate changes found in both fabric stimulations. Therefore significant difference between the heart rate changes of Fabrics 7 and 8 are able to be defined in these time windows. The mean of the difference at 80% confidence level is less than zero, which shows that viewers' heart rate deceleration is larger in response to Fabric 7 than Fabric 8 in the 4th and 7th seconds after the fabric presentation. The significant differences are only found in two time windows, and it is insufficient for drawing conclusions regarding the difference in viewer's emotional response between the two fabrics.

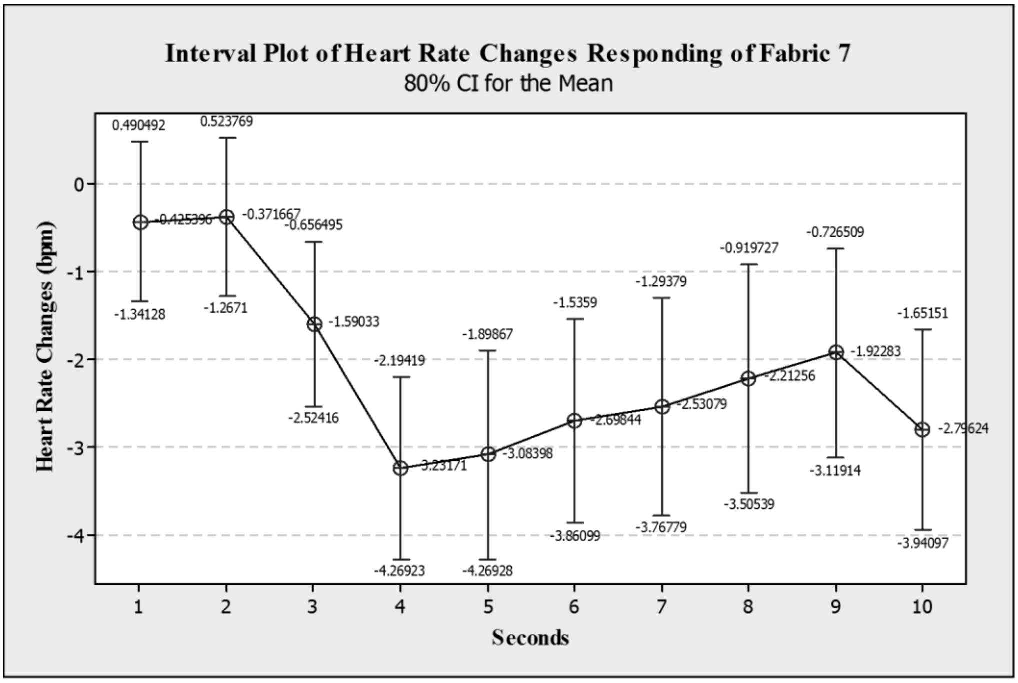


Figure 5-40 People's heart rate changes responding to the viewing of Fabric 7.

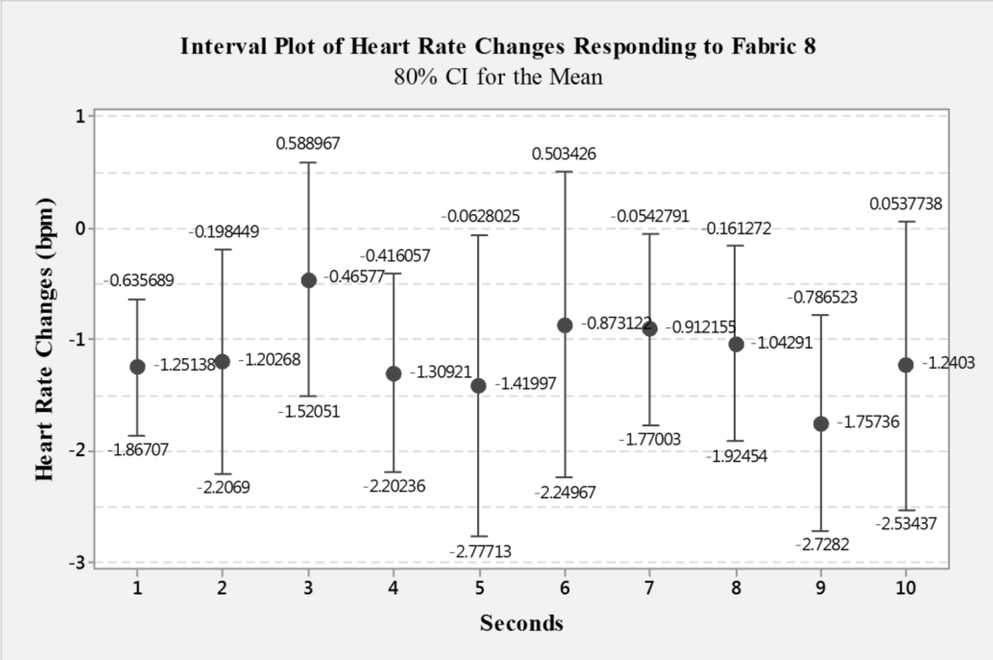


Figure 5-41 People's heart rate changes responding to the viewing of Fabric 8.

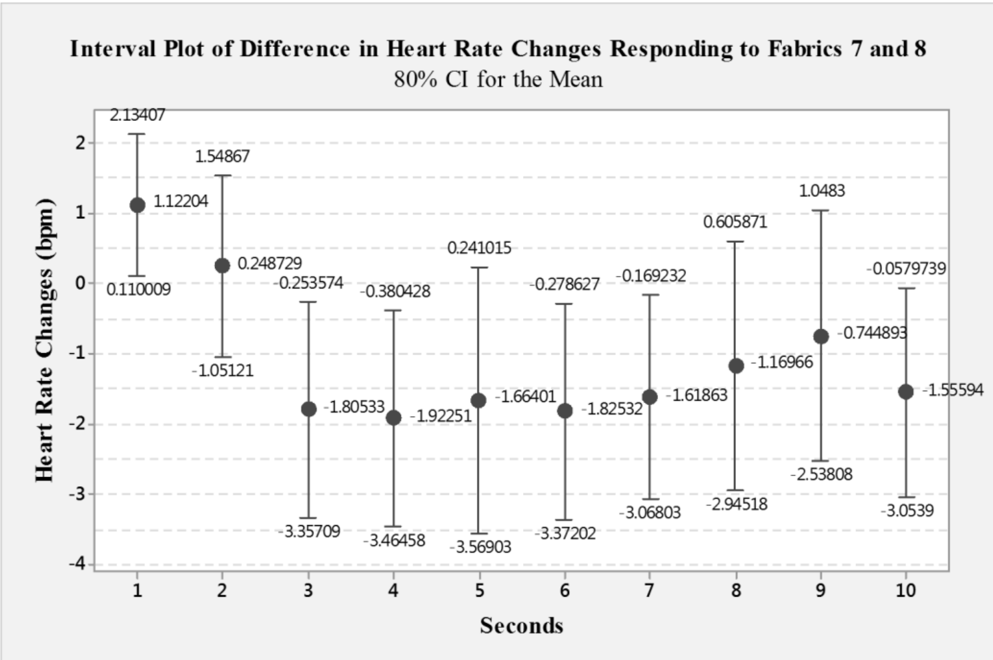


Figure 5-42 Differences of people's heart rate changes when viewing Fabrics 7 and 8.

5.3.4.4 Subjective analysis

The rating scores by the twenty participants of the Valence, Arousal and Likert scales to Fabrics 7 and 8 are reported in Appendix C.46. One participant's rating scores on the three scales were removed because they were found to be unsuitably biased. The difference between the rating scores of Fabrics 7 and 8 was calculated on each scale. At 80% confidence level, the mean of the differences is presented in Figure 5-43. The significant difference was only found in the Arousal scale. A confidence interval estimation at 95% confidence level shows the following:

Mean = -1.211,

Standard Deviation = 2.226,

Standard Error of the Mean = 0.511,

Confidence interval between -2.283 and -0.138, T=-2.37 and p-value = 0.029.

It can therefore be concluded that Fabric 8 is rated to have a greater exciting effect than Fabric 7. In the Valence and Likert scales, the mean of the difference is undefined, neither positive nor negative, and therefore it has no significant difference, revealing no difference in people's valence response or preference between Fabrics 7 and 8.

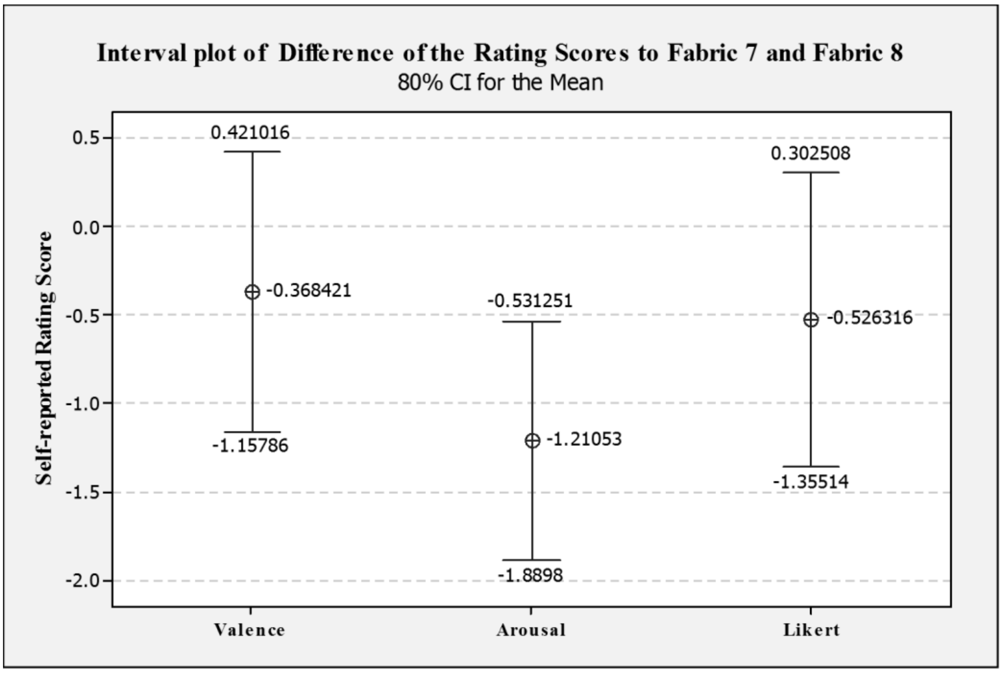


Figure 5-43 People's difference in the subjective rating scores when viewing Fabrics 7 and 8.

5.3.4.5 Result interpretation summary

Significant results were found in people's subjective evaluation as well as their brain wave response to the viewing of Fabrics 7 and 8. The significant differences observed in the current experiment are summarised in Figure 5-44. In the subjective evaluation, significant difference was observed in the rating scores of the Arousal scale, in which the mean of the differences is less than zero at 95% confidence level with p-value 0.029. This result shows that the rating score of Fabric 8 is significantly higher than the rating score of Fabric 7, which indicates that people consciously consider Fabric 8 as more exciting than Fabric 7. In their brain wave measurement, significant results were found in the Delta, Theta, and Gamma frequency power response. Fabric 8 evoked higher Delta power responses in the prefrontal and occipital regions of the brain at 80% and 85% confidence levels. The increased Delta power response in the frontal and occipital regions of the brain has been found in the viewing of emotional stimuli compared with neutral stimuli. [168, 169] Therefore, the current observation might indicate that Fabric 8 has more emotional effect than Fabric 7. Fabric 8 also evoked significant higher Theta power response in the prefrontal region of the brain. The increased Theta power in the frontal region of the brain has been found to have an association with emotional facial expression compared with neutral expression [150]. Therefore, the current observation of the Theta power response might also infer that Fabric 8 has more emotional effect than Fabric 7. Therefore, Fabric 8 has a more exciting effect on people's emotional responses than Fabric 7.

<table>
<tr><th rowspan="3">Fabric</th><th colspan="3">Subjective Evaluation</th><th colspan="2">Brain Wave Activity</th><th>Cardiac Activity</th></tr>
<tr><th colspan="2">SAM Scales</th><th rowspan="2">Likert Scale</th><th rowspan="2">Frequency Band Powers of the Brain Waves</th><th rowspan="2">Frontal Alpha Asymmetry Index</th><th rowspan="2">Heart Rate Changes</th></tr>
<tr><th>Valence Scale (Pleasant – Unpleasant)</th><th>Arousal Scale (Exciting – Calm)</th></tr>
<tr><td>Fabric 7

Vs

Fabric 8</td><td>No significant difference was found.</td><td>Fabric 8 was rated as more exciting than Fabric 7 at 95% confidence level, p-value 0.029.</td><td>No significant difference was found.</td><td>• Delta frequency power: Fabric 8 evoked significantly higher Delta power response in the frontal and occipital regions of the brain than Fabric 7 at over 80% confidence level, which might infer that Fabric 8 has more emotional effect than Fabric 7.

• Theta frequency power: At 90% confidence level, Fabric 8 triggers higher Theta power than Fabric 7 in the prefrontal area of the brain, which might infer that Fabric 8 has more emotional effect than Fabric 7.

• Gamma frequency power: At 95% confidence level, Fabric 7 triggers significantly higher Gamma power at the left frontal area of the brain, which might infer Fabric 7 has a negatively unpleasant effect on people’s emotional response.</td><td>No significant difference was found.</td><td>No significant difference was found.</td></tr>
</table>

Figure 5-44 Summary of established significant differences in people’s responses to the viewing of Fabrics 7 and 8.

5.4 Investigation of the Pattern-changing Effect on People's Visual Response

In this section, we investigated the visual effect evoked by the pattern change of each SMART fabric. People's visual responses were measured in their visual brain by the event-related potential (ERP) method. The experiment was carefully designed and conducted. The amplitude and latency of the ERP component evoked by the viewing of the two paired patterns of each fabric were analysed and compared. The significant differences were determined by the statistical hypothesis testing technique. When differences were established, the confidence intervals of the mean of these differences were computed and analysed, so that the differences between people's visual responses to the two paired patterns were revealed.

5.4.1 *Event-related potential experiment*

The 20 participants in the previous experiment took part in the current experiment. Their details are reported in Chapter 3, section 3.2.1. The experimental stimuli were the same as the 8 fabric patterns described in section 5.1.2. The experimental slides were the same as the experimental slides in the first part of the experiment in Chapter 3, section 3.2.3, but under different order and duration, which are shown in Figure 5-45. The random length of the baseline period before the pattern stimulus onset was between 1 and 1.5 seconds and the pattern stimulus was presented for 1 second. All pattern stimuli were shuffled randomly before presentation and each of them was presented 30 times. The slides were pre-programmed by bespoke scripts in the "Presentation" software and the coding of these scripts is reported in Appendix C.47. The procedure of the experiment follows the same as in Chapter 3, sections 3.2.5.1 and 3.2.5.2. The only differences are without ECG recording.

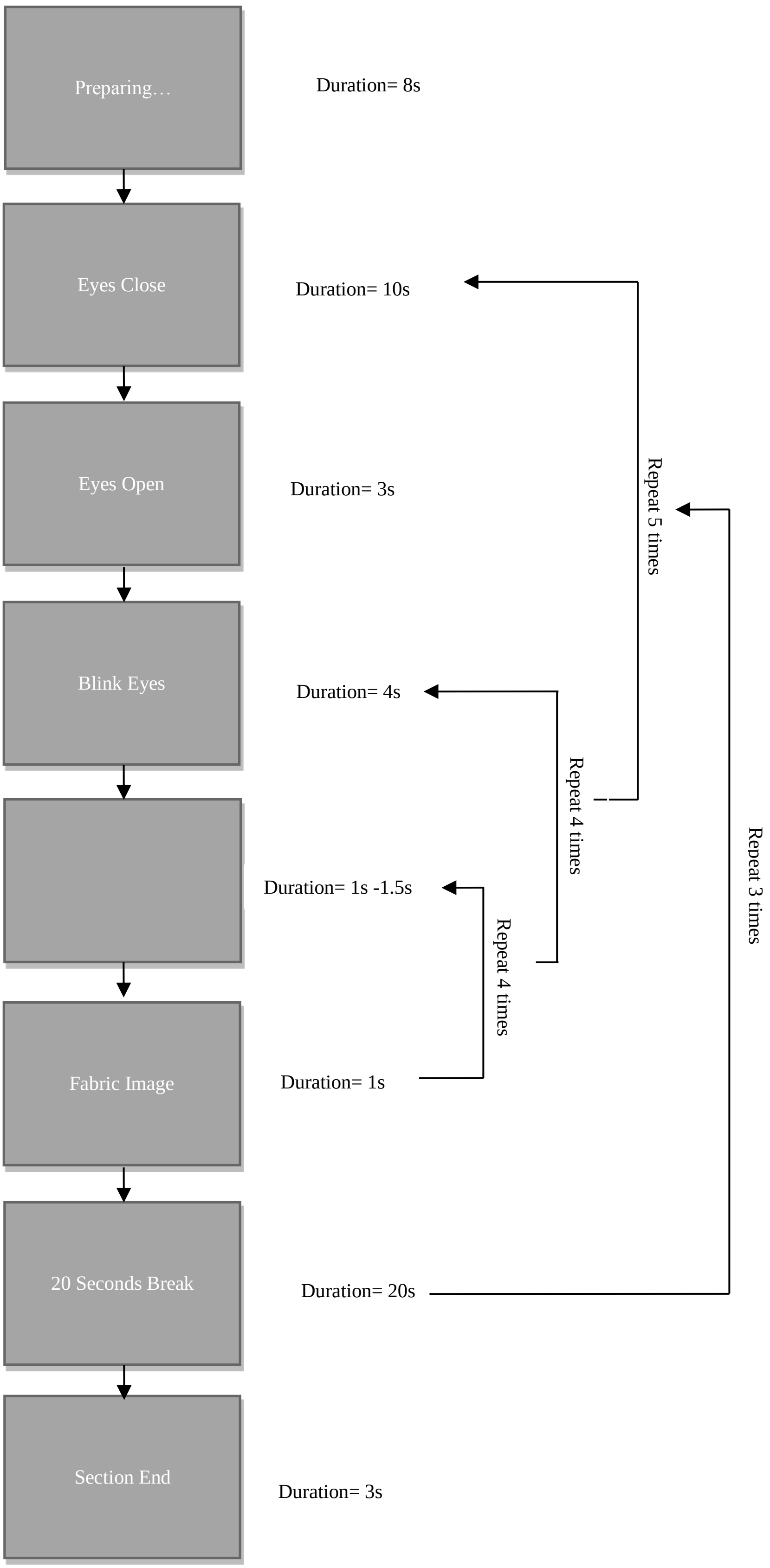


Figure 5-45 A diagram of the slides with the timing used in the event-related potential experiment.

5.4.2 *Data acquisition and processing*

Each participant's visual ERP evoked by the pattern stimuli was measured based on the EEG signals recorded in the experiment. The EEG signal recording and pre-processing follow the same procedure as Chapter 3, section 3.3.1. The ERP was calculated in EEGLAB based on the 30 EEG epochs corresponding to each pattern stimulus, which start at 200 milliseconds before the pattern onset until 1000 milliseconds afterwards. The visual ERP is the ERP measured on the O1 and O2 electrode channels located in the visual brain. Three prominent components have been found to occur in each visual ERP wave. They are the first positive component P1, the first negative component N1 and second positive component P2. The amplitude and latency of each component were analysed. According to literature, there were two methods to measure the amplitude of the components N1 and P2. In the first method, the amplitude of the component was the local peak value. In the second method, the amplitude of component N1 was measured as the difference between the local peak of component N1 and the preceding P1 (P1 peak – N1 peak); the amplitude of component P2 was measured as the difference between the local peak of component P2 and the preceding N1 (P2 peak – N1 peak). Both methods have strengths and shortcomings [97, p229-237]. The current experiment used both methods so that one can complement the other. The local amplitude and latency of the three ERP components were detected by self-written scripts in MATLAB. The scripts are shown in Appendices C.48 – C.50. The data of the twenty participants' visual ERP components were then imported to Minitab for further statistical analysis.

5.4.3 *Data analysis and results*

Firstly, the grand average of the twenty participants' visual ERPs evoked by each stimulus was computed and visualised in a graph for both the O1 and O2 electrode channels using by EEGLAB. The significant difference of the visual ERP between the two paired patterns was calculated along the grand ERP wave using EEGLAB with confidence level at 95%. Secondly, differences of the amplitude (μv) and latency (ms) of the ERP components P1, N1 and P2 evoked by the two paired patterns were calculated by the hypothesis test, and when the differences were obtained, the mean of the differences was calculated by confidence interval estimation. The analysis results of the two paired patterns of each SMART fabric are reported as follows.

5.4.3.1 The differences in people's visual responses to Fabrics 1 and 2

The grand average of the twenty participants' visual ERPs evoked by Fabrics 1 and 2 were computed and visualised by EEBLAB, shown in Figure 5-46. The ERP waves of the O1 channel are shown in the top graph; and the ERP waves of the O2 channel are shown in the bottom graph. Each ERP wave starts at 200 milliseconds before the pattern onset continuing until 1000 milliseconds afterwards. The following components are observed as prominent; component P1 at around 100 milliseconds, component N1 at around 150 milliseconds and component P2 between 200 to 300 milliseconds. The vertical grey lines in the graphs indicate the significant differences between the ERPs of two pattern stimulations at 95% confidence level, which were calculated by using EEGLAB. The results show that significant differences occur in the N1 component of the ERP in both the O1 and O2 channel locations.

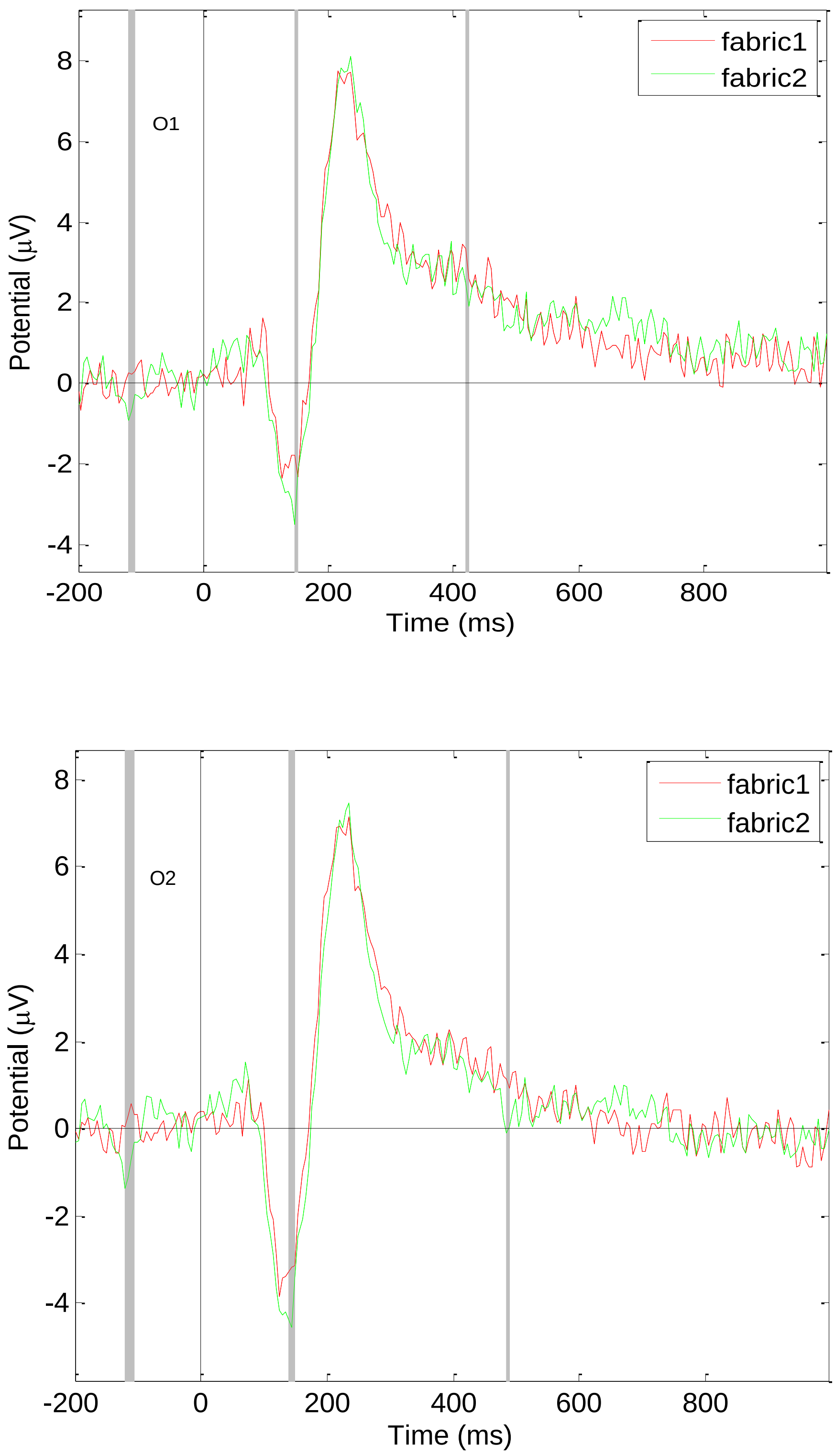


Figure 5-46 Grand average ERP of the O1 and O2 electrode channels responding to Fabrics 1 and 2. The grey lines show the significant differences with p-value < 0.05.

The differences of the twenty participants' ERP components evoked between Fabrics 1 and 2 stimulations are reported in Appendices C.51 – C52. The differences of the amplitudes of components N1 and P2 that were obtained by using the second amplitude measuring method as described in section 5.4.2 are reported in Appendix C.53. Significant differences of the amplitude or latency of the ERP components are reported in Figure 5-47.

In component N1, significant difference was found in the latency of the O1 channel location. The mean of the difference at 90% confidence level is over zero, which shows that Fabric 2 triggers an earlier component N1 than Fabric 1 in the left of the visual brain. Significant difference was also found in the amplitude of component N1 in the O2 channel location. The mean of the difference at 90% confidence level is over zero, which shows that Fabric 2 triggers a larger component N1 than Fabric 1 in the right of the visual brain. The latency of component N1 has been also found to be sensitive to the intensity of the visual stimuli. The latency is shorter in response to the stimuli with higher brightness [170]. In the current investigation, the difference of the visual intensity between Fabrics 1 and 2 in the viewer's visual brain response is clearly evident in which Fabric 2 has higher visual intensity than Fabric 1. The amplitude of component N1 has also been found to be influenced by the visual parameters of the stimuli [2, p196-203]. In the current investigation, Fabric 2 triggers a larger amplitude of component N1 than Fabric 1, which shows that Fabric 2 has higher visual intensity than Fabric 1. In component P2, significant difference was found in the latency of the component in the O2 channel location. The mean of the difference at 90% confidence level is less than zero, which shows that Fabric 1 triggers an earlier component P2 than Fabric 2 in the right of the visual brain.

Therefore, the viewing of the pattern-changing effect of SMART fabric D as from Fabrics 1 to 2 evoked different responses in the visual brain. Fabrics 1 and 2 have almost identical patterned appearance, except that Fabric 1 is very faint in grey and white colours, whilst Fabric 2 is much clearer and better defined in black and white colours. The current results show that the difference intensity of the fabric patterns causes different visual brain responses, in which clearer and well defined patterns evoke an earlier and larger ERP component N1 and faint patterns evoke an earlier component P2.

O1 Electrode Channel		
N1	Latency (ms)	N Mean StDev SE Mean 90% CI T P 20 4.50 9.99 2.23 (0.64, 8.36) 2.02 0.058
O2 Electrode Channel		
N1	Amplitude (µv)	N Mean StDev SE Mean 90% CI T P 20 1.023 2.527 0.565 (0.046, 2.000) 1.81 0.086
P2	Latency (ms)	N Mean StDev SE Mean 90% CI T P 20 -9.50 12.97 2.90 (-14.51, -4.49) -3.28 0.004

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-47 Significant differences observed in the components of the visual ERP waves of Fabrics 1 and 2.

5.4.3.2 The differences in people's visual responses to Fabrics 3 and 4

The grand average of the twenty participants' visual ERP evoked by Fabrics 3 and 4 were computed and visualised by EEGLAB, shown in Figure 5-48. The ERP waves of the O1 channel are shown in the top graph; and the ERP waves of the O2 channel are shown in the bottom graph. Each ERP wave starts at 200 milliseconds before the pattern onset, continuing until 1000 milliseconds afterwards. The following components are observed as prominent; component P1 at around 100 milliseconds, component N1 at around 150 milliseconds and component P2 between 200 to 300 milliseconds. The vertical grey lines in the graphs indicate the significant differences between the ERPs of the two pattern stimulations at 95% confidence level, which were calculated by using EEGLAB. The results show that significant differences occur in the N1 and P2 components of the ERP in both the O1 and O2 channel locations.

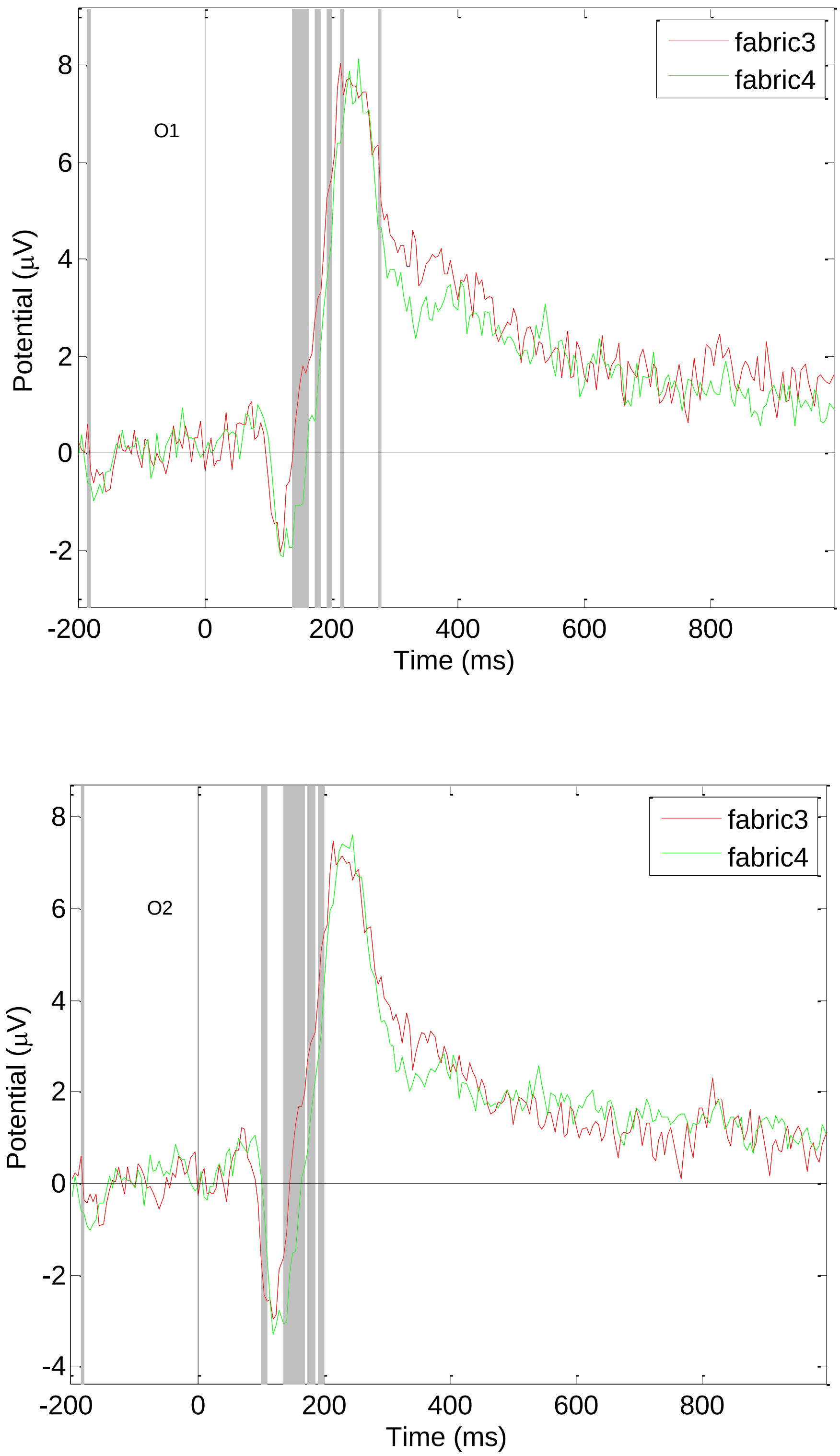


Figure 5-48 Grand average ERP of the O1 and O2 electrode channels responding to Fabrics 3 and 4. The grey lines show the significant differences with p-value < 0.05.

The differences of the twenty participants' ERP components evoked between Fabrics 3 and 4 stimulations are reported in Appendices C.54 – C.55. The differences of the amplitudes of components N1 and P2 that were obtained by using the second amplitude measuring method are reported in Appendix C.56. Significant differences of the amplitude or latency of the ERP components are reported in Figure 5-49. The significant differences were found in the ERP components P1, N1 and P2 of the O1 channel location and the ERP component N1 of the O2 channel location.

In component P1, significant difference was found in the amplitude in the O1 channel location. The mean of difference is less than zero at 85% confidence level, which shows that Fabric 4 evoked a larger component P1 than Fabric 3 in the left of the visual brain. In component N1, significant difference was found in the amplitude in both the O1 and O2 channel locations. The mean of the differences is less than zero at 80% and 83% confidence levels, which shows that Fabric 3 evoked a larger component N1 than Fabric 4 in both sides of the visual brain. Significant difference was also found in the latency of component N1 in the O1 channel location. The mean of the differences is less than zero at 89% confidence level, which shows that Fabric 3 evoked an earlier component N1 than Fabric 4 in the left of the visual brain. The latency of component N1 has been found to be shorter in response to the stimuli with higher brightness [170] and the amplitude of component N1 has been found to be influenced by the visual parameters of the stimuli [2, p196-203]. The current results reveal different visual parameters between Fabrics 3 and 4, in which Fabric 3 might have higher visual intensity than Fabric 4. In component P2, significant difference was found in the amplitude in the O1 channel location. The mean of the difference is less than zero at 85% confidence level, which shows that Fabric 4 evoked a bigger component P2 than Fabric 3 in the left of the visual brain.

Therefore, the viewing of the pattern-changing effect of SMART fabric E as from Fabric 3 to 4 triggered different responses in the visual brain. Both patterns contain small square shapes of the same size. The difference is that Fabric 3 is symmetrical with continuously repeating squares, whilst Fabric 4 has an asymmetrical structure with randomly arranged squares and rectangular shapes, some of which are filled with intense black colour. Current results show that these different pattern features evoke different responses in the visual brain, in which symmetrical patterns with regular repeating elements trigger larger and earlier ERP component N1; whilst asymmetrical patterns containing irregular elements trigger larger components P1 and P2.

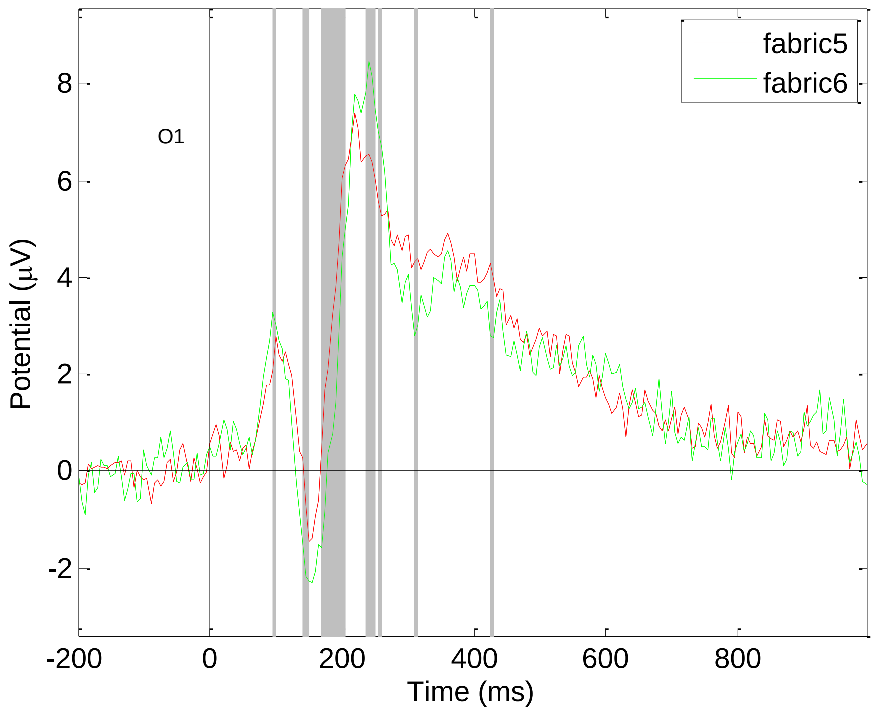
O1 Electrode Channel		
P1	Amplitude (µv)	N Mean StDev SE Mean 85% CI T P 20 -0.905 2.641 0.591 (-1.791, -0.019) -1.53 0.142
N1	Amplitude (µv)	N Mean StDev SE Mean 80% CI T P 20 -1.333 4.044 0.904 (-2.534, -0.133) -1.47 0.157
	Latency (ms)	N Mean StDev SE Mean 89% CI T P 19 -3.68 9.40 2.16 (-7.31, -0.06) -1.71 0.105
P2	Amplitude (µv)	N Mean StDev SE Mean 85% CI T P 18 -0.645 1.785 0.421 (-1.279, -0.011) -1.53 0.143
O2 Electrode Channel		
N1	Amplitude (µv)	N Mean StDev SE Mean 83% CI T P 20 -1.074 3.319 0.742 (-2.132, -0.015) -1.45 0.164

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-49 Significant differences observed in the components of the visual ERP waves of Fabric 3 and Fabric 4.

5.4.3.3 The differences in people's visual responses to Fabrics 5 and 6

The grand average of the twenty participants' visual ERP evoked by Fabrics 5 and 6 were computed and visualised using EEBLAB, as shown in Figure 5-50. The ERP waves of the O1 channel are shown in the top graph; and the ERP waves of the O2 channel are shown in the bottom graph. Each ERP wave starts at 200 milliseconds before the pattern onset and continues until 1000 milliseconds afterwards. The following components are observed as prominent; component P1 at around 100 milliseconds, component N1 between 150 to 200 milliseconds and component P2 around 250 milliseconds. The vertical grey lines in the graphs indicate the significant differences between the ERPs of the two pattern stimulations at 95% confidence level, which were calculated by using EEGLAB. The results show that significant differences occur in the P1, N1 and P2 components of the ERP in the O1 channel location, and in the N1 and P2 components of the ERP in the O2 channel location.



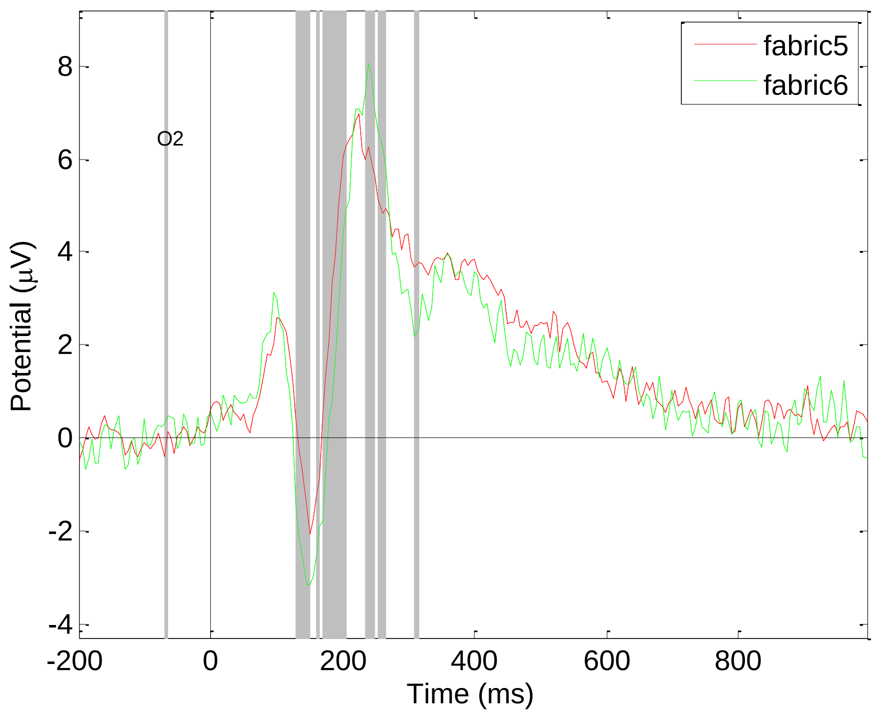


Figure 5-50 Grand average ERP of the O1 and O2 electrode channels responding to Fabrics 5 and 6. The grey lines show the significant differences with p-value < 0.05.

The differences of the twenty participants' ERP components evoked between Fabrics 5 and 6 are reported in Appendices C.57 – C.58. The differences of the amplitudes of components N1 and P2 calculated by the second measuring method are reported in Appendix C.59. Significant differences found in the amplitude and latency of the ERP components are reported in Figure 5-51.

In component N1, significant difference was found in the amplitude in both the O1 and O2 channel locations. The mean of difference is over zero at confidence level over 95%, which shows that Fabric 6 evokes a larger component N1 than Fabric 5 on both sides of the visual brain. The amplitude of component N1 has been found to be influenced by the visual parameters of the stimuli [2, p196-203]. Therefore, the current results might reveal the difference of the visual parameter between Fabric 5 and 6. In component P2, significant difference was found in the amplitude in both the O1 and O2 channel locations. The mean of the difference is less than zero at 95% confidence level, which shows that Fabric 6 evokes a larger component P2 than Fabric 5 on both sides of the visual brain. A difference was also found in the latency of component P2 in the O2 channel location. The mean of the difference is less than zero at 95% confidence level, which shows that Fabric 5 triggered an earlier component P2 in the right of the visual brain.

Therefore, the viewing of the pattern-changing effect of SMART fabric G as from Fabric 5 to 6 evoked significantly different electrical activities of the visual brain. These two patterns have symmetrical structures and contain regularly repeating diamond shapes. The difference between them is that Fabric 5 has smaller diamond shapes compared to Fabric 6, so that Fabric 5 is loose and weak, whilst Fabric 6 is larger and more intense than Fabric 5. Current results show clear evidence that the intense effect produced by changing the size of the elements in a pattern causes different responses of the visual brain, in which more intense patterns trigger larger components N1 and P2, indicating a larger brain response; whilst loose and weak patterns evoke an earlier component P2 in the visual ERP.

O1 Electrode Channel		
N1	Amplitude (μv)	N Mean StDev SE Mean 95% CI T P 20 2.143 2.662 0.595 (0.898, 3.389) 3.60 0.002
P2	Amplitude (μv)	N Mean StDev SE Mean 95% CI T P 20 -3.024 3.271 0.731 (-4.555, -1.493) -4.13 0.001
O2 Electrode Channel		
N1	Amplitude (μv)	N Mean StDev SE Mean 98% CI T P 20 2.201 2.469 0.552 (0.799, 3.603) 3.99 0.001
P2	Amplitude (μv)	N Mean StDev SE Mean 95% CI T P 20 -2.943 3.048 0.681 (-4.369, -1.516) -4.32 0.000
	Latency (ms)	N Mean StDev SE Mean 95% CI T P 20 -7.75 10.82 2.42 (-12.81, -2.69) -3.20 0.005

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-51 Significant differences observed in the components of the visual ERP waves of Fabric 5 and Fabric 6

5.4.3.4 The differences in people's visual responses to Fabrics 7 and 8

The grand average of the twenty participants' visual ERP evoked by Fabrics 7 and 8 were computed and visualised by EEBLAB, as shown in Figure 5-52. The ERP waves of the O1 channel are shown in the top graph; and the ERP waves of the O2 channel are shown in the bottom graph. Each ERP wave starts at 200 milliseconds before the pattern onset and continues until 1000 milliseconds afterwards. The following components are observed as prominent; component P1 at around 100 milliseconds, component N1 between 150 to 200 milliseconds and component P2 around 250 milliseconds. The vertical grey lines in the graphs indicate the significant differences between the ERPs of the two pattern stimulations at 95% confidence level, which were calculated by using EEGLAB. The results show that significant differences occur in the N1 and P2 components of the ERP in the O2 channel location.

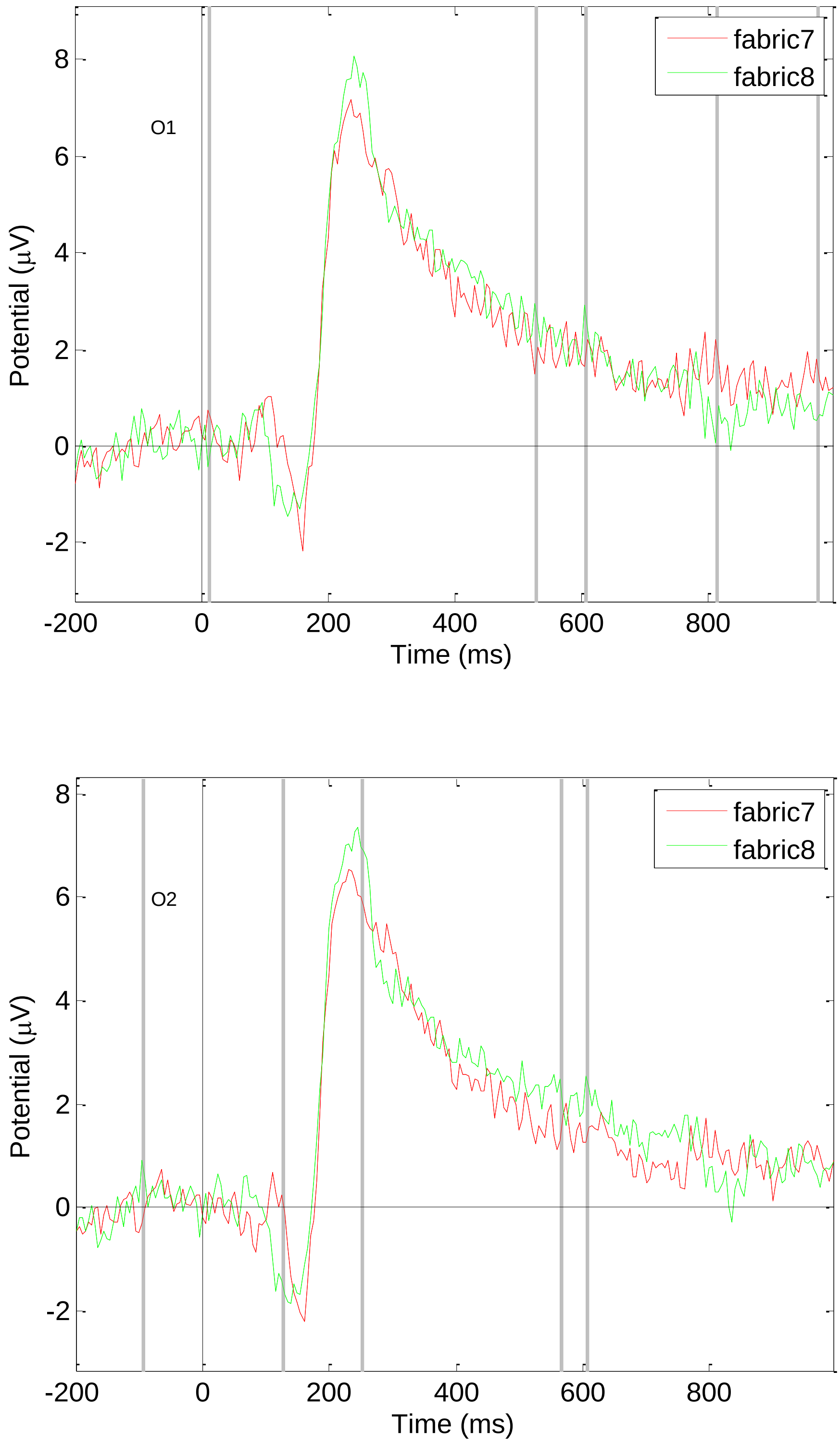


Figure 5-52 Grand average ERP of the O1 and O2 electrode channels responding to Fabrics 7 and 8. The grey lines show the significant differences with p-value < 0.05.

The difference of the twenty participants' ERP components evoked between Fabrics 7 and 8 are reported in Appendices C.60 – C.61. The differences of the amplitudes of components N1 and P2 calculated by the second measuring method are reported in Appendix C. 62. Significant differences found in the amplitude and latency of the ERP components are reported in Figure 5-53.

In component P1, significant difference was found in the latency in the O1 channel location. The mean of the difference is less than zero at 90% confidence level, which shows that Fabric 7 triggered an earlier component P1 than Fabric 8 in the left of the visual brain. In component N1, significant difference was found in the amplitude in the O1 channel location. The mean of the difference is less than zero at 95% confidence level, which shows that Fabric 7 evoked a larger component N1 than Fabric 8 in the left of the visual brain. Significant difference was also found in the latency of component N1 in both the O1 and O2 channel locations. The mean of the differences is over zero at 95% and 88% confidence levels, which shows that Fabric 8 evoked an earlier component N1 than Fabric 7 in both sides of the visual brain. The latency of component N1 has been found to be shorter in response to the stimuli with higher brightness [170] and the amplitude of component N1 has been found to be influenced by the visual parameters of the stimuli [2, p196-203]. Therefore, the current result might reveal the different visual parameter between Fabrics 7 and 8, and infer that Fabric 8 has higher visual intensity than Fabric 7. In component P2, significant difference was found in the amplitude in both the O1 and O2 channel locations. The means of differences are less than zero at 95% and 91% confidence levels, which shows that Fabric 8 evoked a larger component P2 than Fabric 7 in both sides of the visual brain. Significant difference was also found in the latency of component P2 in the O1 channel location. The mean of difference is over zero at 80% confidence level, which shows that Fabric 8 triggers an earlier component P2 than Fabric 7 in the left of the visual brain.

Therefore, the viewing of the pattern-changing effect of SMART fabric F as from Fabric 7 to 8 triggered different responses in the visual brain. Although both patterns contain larger square shapes, Fabric 7 has a symmetrical structure with regularly repeating square shapes, whilst Fabric 8 has the same squares as Fabric 7 but they are non-repeating and some filled with black intense colour or smaller squares within. As a result, Fabric 8 is more complex than Fabric 7 and non-symmetrical. Current results show that these differences trigger different responses in the visual brain, in which the relatively simple and symmetrical patterns trigger an earlier component P1 and a larger component N1; whilst the complex and asymmetrical patterns trigger an earlier component N1 and a larger and earlier component P2.

O1 Electrode Channel		
P1	Latency (ms)	N Mean StDev SE Mean 90% CI T P 18 -8.06 16.37 3.86 (-14.77, -1.34) -2.09 0.052
N1	Amplitude (μv)	N Mean StDev SE Mean 95% CI T P 17 -11.33 5.91 1.43 (-14.37, -8.29) -7.91 0.000
	Latency (ms)	N Mean StDev SE Mean 95% CI T P 18 10.28 17.10 4.03 (1.77, 18.78) 2.55 0.021
P2	Amplitude (μv)	N Mean StDev SE Mean 95% CI T P 17 -1.934 2.992 0.726 (-3.473, -0.396) -2.67 0.017
	Latency (ms)	N Mean StDev SE Mean 80% CI T P 19 3.95 11.74 2.69 (0.37, 7.53) 1.47 0.160
O2 Electrode Channel		
N1	Latency (ms)	N Mean StDev SE Mean 88% CI T P 20 5.50 14.95 3.34 (0.06, 10.94) 1.65 0.116
P2	Amplitude (μv)	N Mean StDev SE Mean 91% CI T P 20 -1.253 3.093 0.692 (-2.488, -0.017) -1.81 0.086

*StDev: Standard Deviation. SE Mean: Standard error of the mean. CI: Confidence interval. P: p-value.

Figure 5-53 Significant differences observed in the components of the visual ERP waves of Fabric 7 and Fabric 8.

5.5 Summary and Discussion

The differences of people's emotional response to the paired patterned appearances of four SMART fabrics D, E, G and F have been investigated in the current chapter. The combination of brain wave and cardiac activity with subjective evaluation has revealed the significant difference of people's emotional response to each paired pattern. According to the current observation, when SMART fabric D changes its pattern as from Fabrics 1 and 2, it evokes more pleasantness in people's response; when SMART fabric E changes as from Fabric 3 to 4, it triggers a higher level of excitement; when SMART fabric G changes as from Fabric 5 to 6, it influences more pleasant experience; and when SMART fabric F changes as from Fabric 7 to 8, it evokes a higher arousal effect in people's emotions.

In Chapter 3, we have found that repeating patterns have a more pleasant effect on people's emotions than non-repeating patterns, and intense patterns evoke higher levels of excitement than weak patterns. In the current chapter, these emotional effects had been further investigated with real fabrics. Fabrics 3 and 4, Fabrics 7 and 8 are two pairs of repeating/non-repeating patterns that were developed from patterns E1 and E2, and patterns F1 and F2 described in Chapter 3. Current investigation shows that non-repeating patterns (Fabrics 4 and 8) evoke a higher level of excitement in people's response than repeating patterns (Fabric 3 and 7), which is an additional finding to this investigation. Fabrics 1 and 2, and Fabrics 5 and 6 are two pairs of weak/ intense patterns that were developed from patterns D1 and D2, and patterns G1 and G2 described in Chapter 3. Current investigation shows that intense patterns (Fabrics 2 and 6) evoke a higher level of excitement in people's emotional response than weak patterns (Fabrics 1 and 5), which is consistent with the result in the previous investigation. The current investigation also shows that intense patterns (Fabrics 2 and 6) have a more pleasant effect than weak patterns (Fabrics 1 and 5), which is an additional finding to this investigation. These additional findings might be caused by the differences of the material that presents the pattern. In the previous investigation, the patterns were drawn and presented by computer graphicx; whilst in the current investigation the patterns were constructed and presented on knitted fabrics. The characteristics of the fabric structure and surface might cause differences in the emotional effect. Further study is required to clarify this matter.

The viewer's visual brain response to the paired patterns of each SMART fabric has been investigated in the current chapter. ERP measurement was used to inspect the visual brain activity when responding to the patterns. Through analysing the amplitude and latency of the observed components in the evoked ERP waves, differences in the visual brain response to the paired patterns were found. Current observations show that each paired pattern triggers different responses in the visual brain. This investigation has demonstrated that it is possible to use pre-determined patterns on interactive fabric in order to evoke different visual response from the viewers, and also indicates that some pattern features might influence the components of the visual ERP, hence effecting on the visual brain response. In current observations, Fabrics 2, 3, 6, and 7 triggered significant higher amplitudes of component N1 than their paired Fabrics 1, 4, 5 and 8. The main difference between these two groups of pattern is that the first group is better defined, much clearer and higher in contrast than the second group. In detail, Fabric 2 is almost identical to Fabric 1 but has a higher contrast; Fabric 6 has diamond shapes and symmetrical structure as Fabric 5, however its larger diamond shapes make it better defined and bold; and symmetrical patterns Fabrics 3 and 7 are simpler and more easily defined than asymmetrical Fabrics 4 and 8. Therefore, this result indicates that well defined, clear and high contrast patterns might trigger a larger component N1, which means a bigger response in the visual brain. Furthermore, significant difference has been found in the amplitude of component N1 evoked by Fabrics 3 and 4, Fabrics 7 and 8. The repeating patterns (Fabrics 3 and 7) evoke a larger component N1 than non-repeating patterns (Fabrics 4 and 8). This result indicates that a pattern that contains regularly repeating elements, symmetrical and continuous structure might evoke larger visual brain response compared with a non-repeating pattern that has irregular elements, asymmetrical and discontinuous features. There is less known about the influence of visual parameters on component P2 in literature. Current observations show that weak patterns (Fabrics 1 and 5) triggered an earlier component P2 than intense patterns (Fabrics 2 and 6), and non-repeating patterns (Fabrics 4 and 8) evoked a larger component P2 than repeating patterns (Fabric 3 and 7). These results indicate that the latency of component P2 might be sensitive to the intense effect of patterns, and the amplitude of component P2 might be larger to patterns that have irregular elements and asymmetrical features. Finally, differences of component P1 was only observed in pairs of Fabrics 3 and 4, and Fabrics 7 and 8. This result might indicate that component P1 is affected by the features of symmetry and continuity but not the weak and intense effects.

When combining the visual and emotional effects of the paired patterns of each SMART fabric as shown in Figure 5-54, it shows that there may be a connection between people's visual brain responses and their emotional experience to pattern. Most significant results of the visual brain response to the effective patterns were found in component N1, which shows that the amplitude and latency of component N1 may have a relation to emotional effect. In detail, Fabrics 2 and 6 containing significantly more pleasant and exciting effects, trigger significantly larger component N1 with confidence level over 90%, compared to their paired patterns that contain less pleasant and exciting effects. Therefore, the amplitude of component N1 in visual ERP may be associated with the pleasant and arousal effect in emotion. Although it is partially found in our results, it indicates that there is a direct link between people's visual brain responses and their emotional experience. Since visual brain response contains no thinking or memory and it happens before any emotional response, there may be an influence on human emotional experience from the time of seeing the object.

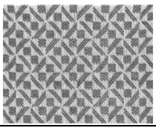
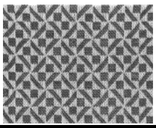
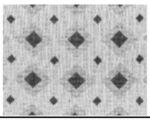
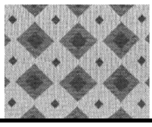
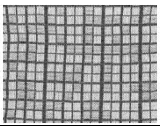
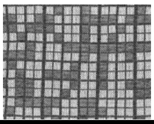
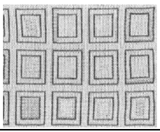
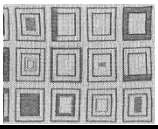
Effective Pattern	Significant Differences in the Visual ERP Components												Significant Differences in Emotional Responses
	Component P1				Component N1				Component P2				
	Amplitude		Latency		Amplitude		Latency		Amplitude		Latency		
	O1	O2	O1	O2	O1	O2	O1	O2	O1	O2	O1	O2	
Fabric 1 												Earlier	
Fabric 2 						Larger	Earlier						More pleasant More exciting
Fabric 5 												Earlier	
Fabric 6 					Larger				Larger				More pleasant More exciting
Fabric 3 					Larger		Earlier						
Fabric 4 	Larger								Larger				More exciting
Fabric7 			Earlier		Larger								
Fabric 8 							Earlier		Larger		Earlier		More exciting

Figure 5-54 Significant differences observed in people's visual brain responses and emotional responses to the viewing of the paired patterns of each SMART fabric.

CHAPTER 6 SUMMARY AND CONCLUSION

The brain is the centre that receives, analyses and stores information that we see, feel, taste, hear and smell, and which allows us to think and respond. The relationship between the human psychological state and its associated brain activity has been unfolding by research into brain science and psychophysiology. This research cuts through design and technology by investigating the relationship between neuroscience and material engineering. It starts by establishing the emotional effect of different characteristics of pattern on the basis of repeating/non-repeating and weak/intense. Repeating patterns contain regularly repeating elements and have symmetrical and continuous features; whilst non-repeating patterns contain irregularly repeating elements and have asymmetrical and discontinuous features. Weak patterns are relatively faint, light and simple compared with intense patterns that are high in contrast, bold and complex. In order to reveal the emotional response of these two patterns, this research carefully constructed the representative characteristics of each pattern without the effect of colour and conducted controlled experiments. The brain and cardiac activity in response to these patterns was measured in twenty subjects along with their subjective self-evaluation. In these experiments, the brain activity of every participant was recorded through an EEG cap with 19 electrodes that covers the whole area of the brain connected to an EEG device. Data from the five frequency band powers of the EEG signals (Delta, Theta, Alpha, Beta and Gamma) were calculated and interpreted in relation to emotion. The frontal EEG asymmetry model was applied for specifically analysing a participant's approach-withdraw emotional experience to the pattern. Simultaneously, each participant's heart rate change in response to pattern was also measured by a connected ECG. In subjective evaluation, every participant's emotion was assessed by using the Self-Assessment Manikin (SAM) system and their preferences by using a 9-point hedonic scale. Each participant's brain wave data, heart rate change and self-evaluation to the two paired patterns were then compared and the significant difference was determined by using statistical hypothesis testing. When a difference was found, the confidence intervals of the mean of the difference were calculated by confidence interval estimation, so that the different emotional effect evoked by each of the two paired patterns were established.

The current research revealed that repeating and non-repeating patterns have different emotional effects. In subjective evaluation, people give repeating patterns significantly higher scores of valence effect than non-repeating patterns. In their brain wave measurement, repeating patterns trigger significantly higher Theta power than non-repeating patterns in the Fz channel location, which is at the midline of the frontal lobe of the brain as indicated with red colour in Figure 6-1. Theta power recorded from the frontal midline of the scalp has been found to be positively correlated with pleasant emotions in published literature, therefore our result shows that repeating patterns have a more pleasing effect than non-repeating patterns.

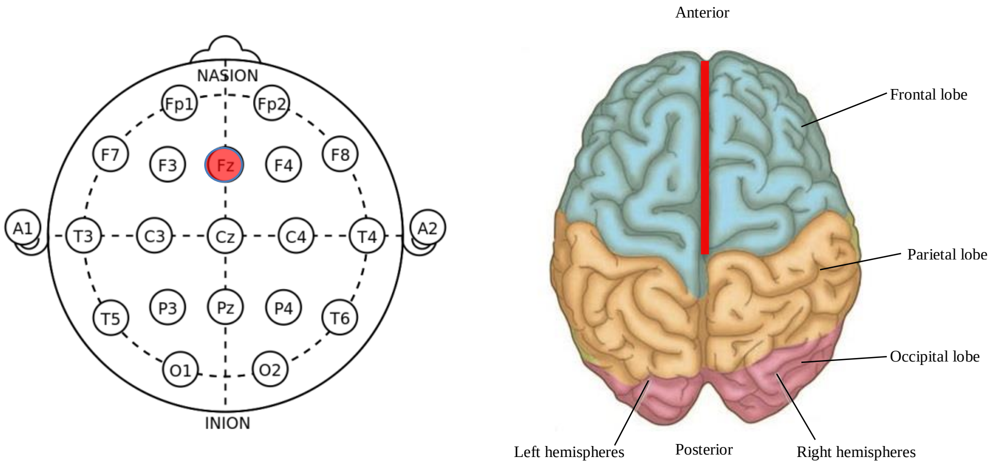


Figure 6-1 Significant higher Theta power triggered at the frontal midline of the brain, when responding to repeating patterns.

The measurement of the asymmetrical activity in the frontal region of the brain shows that people have greater left hemisphere activation when viewing repeating patterns as indicated with red colour in Figure 6-2. According to the frontal EEG asymmetry model, this result shows that people are processing a positive, approached-related emotional experience when responding to repeating patterns. No significant result was found in the asymmetrical activity in the frontal region of the brain when responding to non-repeating patterns, which shows no population approach-withdraw emotional experience to non-repeating patterns.

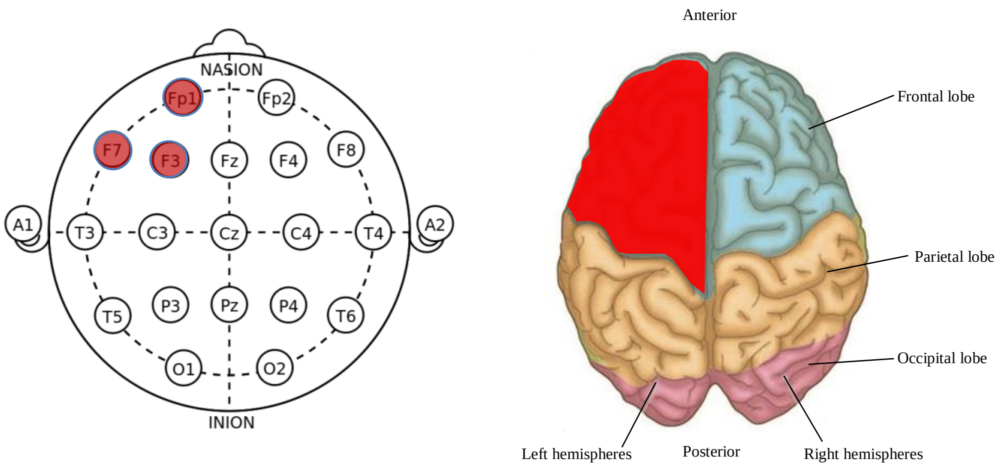


Figure 6-2 Greater relative left hemisphere activation of the brain when viewing repeating patterns.

Additionally, heart rate deceleration was observed in response to both patterns, but it is significantly larger to non-repeating patterns in the initial 4 seconds. A greater heart rate deceleration has been found to be associated with unpleasant stimulation in published literature. Therefore, according to our heart rate measurement, non-repeating patterns have a more unpleasant effect compared to repeating patterns. Combining the results of people's brain wave responses and heart rate changes with their subjective evaluation, we can therefore conclude that a pattern that contains regularly repeating elements, and has symmetrical and continuous characteristics has a more pleasant effect and evokes a more positive emotional experience, than a non-repeating pattern that contains irregular elements, and has asymmetrical and discontinuous characteristics.

In the case of weak and intense patterns, this research has found a significant difference in people's arousal responses. The result of subjective evaluation shows that people consciously react to intense patterns as they are more exciting to view than corresponding weak patterns. Their brain wave measurement shows that intense patterns evoke significantly higher Theta power over the parietal and occipital lobes of the brain than weak patterns. Increasing Theta power in the posterior area of the brain, where the parietal and occipital lobes locate, has been found to respond to higher arousal stimuli in comparison with low arousal stimuli in scientific literature. Therefore, we can conclude that intense patterns have a higher arousal effect than weak patterns, which is also in agreement with the result of subjective evaluation. Consequently, combining the results of brain wave measurement and subjective evaluation, we conclude that a pattern that is high in contrast, bold and complex triggers a higher level of excitement, contrary to a corresponding weak pattern that is faint, light and simple which evokes a calm and relaxing effect.

Although our emotional experiences are personal and subjective, certain things affect us in the same way. The findings of this research show that our brain wave responses and our self-evaluation of our emotions to specific pattern characteristics are alike. It gives an important indication that our emotion is influenced by what we see in our surroundings and pattern plays an important part. In consequence, our findings imply that altering of human emotion through the manipulation of different design attributes may be possible. Understanding of how pattern attributes and their combinations can influence our emotions allows us to design our environment so that we can interact with it in a dynamic way and SMART materials such as textiles allow for this to be done effectively. This hypothesis was tested further by implementing the above findings in textile fabrics.

Further investigation was carried out for implementing and testing these findings by developing textiles that are able to actively influence our emotion by their SMART pattern-changing function. This was achieved by developing a special electrochromic composite yarn, and hence the ability to create pattern-changing effects by successfully knitting them into fabrics, the pattern effect of which was changed through electronic temperature control. Four pattern-changing fabrics were produced. Two can switch pattern between repeating and non-repeating and two between weak and intense patterns. Controlled experiments with the same twenty participants as in the previous investigation were designed and conducted to determine the emotional effect evoked by these pattern changes of each fabric. During the experiments, participants were exposed to the two patterned appearances of each fabric, whilst their EEG and ECG signals were recorded. The subjective evaluation of each participant's emotional response and preference to the patterns were also carried out by using the SAM system and the 9-point hedonic scale. The measured data of every participant's brain wave activity and heart rate change corresponding to each pattern stimulus were analysed and interpreted in relation to his/her emotional response coupled with their subjective evaluation. All recorded participants' responses to the two patterned appearances of each fabric were then compared and the mean of their difference was calculated by using statistical hypothesis testing and confidence interval estimation, so that the difference of the emotional effects evoked by the two pattern changes is established. Significant difference was found in people's emotional responses to the two patterned appearances presented by each pattern-changing fabric. We can now say that it is possible to purposely design switching of fabric patterns to influence specific human emotions. We have therefore established the notion of designing emotional influences in SMART textiles and hence establishing their name as psychotextiles. Psychotextiles can also change their colour and shape through combinations of colour, pattern and shape changes. This research paves the way in how we can implement these SMART functions in development of emotional interactive psychotextiles in the living space.

The emotional effect of purposely designed and developed fabrics with repeating/non-repeating and weak/intense patterns verified and extended our previous results. The intense fabric patterns were found to evoke larger excitement than the corresponding weak patterns, which is consistent with the results of previous investigation. The intense fabric patterns were also found to influence more pleasing sensations than the weak patterns, which is an additional finding to this investigation. The non-repeating fabric pattern was found to have a more exciting effect than the repeating pattern, which is also an additional finding to this investigation. These additional findings might be caused by the characteristics of the fabric structure being a specific artefact rather than abstract as the pattern on a screen and it is also possible that the surface may also influence these results.

Finally, this research also investigated the impact of pattern-changing on the viewers' visual responses by measuring the activity of the visual brain. The visual brain is the centre that processes all visual information that we receive through our eyes. In order to measure the visual brain response to each pattern stimulus, the visual ERP technique was used, in which the two patterned appearances of each fabric were randomly and repeatedly presented to participants whilst their visual brain activity was recorded through EEG. The corresponding EEG signals to each pattern stimulus were then averaged and the result represents the visual brain response to each pattern. Our research has found three prominent components P1, N1 and P2 occurring in the participants' visual ERP wave, and that the amplitude and latency of these components are different between the two patterned appearances of each fabric. This result shows that the pattern change of each fabric triggers different responses in the viewers' visual brains. Some responses are larger and quicker; some are smaller and slower. There is a clear interaction between the pattern-changing function of the fabric and the viewers' visual response. More importantly, a well-defined, clear and high contrast pattern might trigger a larger response in the visual brain; and a repeating pattern that contains regularly repeating elements, symmetrical and continuous features might evoke larger visual brain response than a non-repeating pattern that has irregular elements, asymmetrical and discontinuous features. Although more research is needed in this part of the brain, our results indicate that there is a direct link between the visual and emotional brain.

We have found that our emotions can be influenced by pattern characteristics. If it is the case that our visual responses are also affected by pattern characteristics; and since visual response happens as quickly as 0.1 second after the stimulation onset, which is before any emotional response occurs, then, has our emotional response to patterns been pre-determined as early as in our visual response without us thinking? If these results can be substantiated and extended, our research connecting the visual brain with emotions has implications beyond the pattern effect and textiles and it leads to question how we perceive the world, in neuroscience, psychology and physiology.

Future research is summarised as follows.

- Further investigation of pattern characteristics and their combinations on people's emotional responses.

- Exploration of the combinations of pattern, colour, touch and smell on people's emotional and visual responses.

- Further research on how we can implement different SMART functions of textiles, such as colour, pattern and shape changes, and their combination in development of psychotextiles for our living environment.

- Investigation of how properties of textile fabric could influence its pattern effect and consequently people's emotional responses.

- Further exploration of the visual effect of pattern characteristics.

- Investigation of whether the initial visual brain response has such an influence on the emotional response to a visual stimulation and whether there are implications that may bring in free will in neuroscience, in psychology and physiology.

APPENDIX A

Appendix A.1 A self-written script of Presentation scenario for presenting the slides in the first part of the experiment.

```
#header
scenario = "10 seconds pattern viewing";
default_background_color = 128, 128, 128;
write_codes=true;
pulse_width=20; # default pulse width =5ms
begin;


#SDL
trial {
  trial_duration = 8000;
    picture {
     text {caption = "Preparing..."; font_size = 30; font_color = 255, 255, 255;
     };
     x = 0; y = 0;
  };
  port_code=2;
  code = "Preparation";
}preparation_trial;    # Preparation screen with a white "Preparing..." at the center


trial {
  trial_duration = 10000;
  picture {
     text {caption = "Eyes Close"; font_size = 30; font_color = 255, 255, 255;
     };
     x = 0; y = 0;
  };
  port_code=2;
  code = "EyesClose";
}eyesclose_trial;    # screen with a white "Eyes Close" at the center
```

```
trial {
   trial_duration = 3000;
   picture {
      text {caption = "Eyes Open"; font_size = 30; font_color = 255, 255, 255;
      };
      x = 0; y = 0;
   };
   port_code=2;
   code = "EyesOpen";
}eyesopen_trial;      # screen with a white "Eyes Open" at the center


trial {
   trial_duration = 3000;
     picture {
      text {caption = "Blink Eyes."; font_size = 30; font_color = 255, 255, 255;
      };
      x = 0; y = 0;
   };
   port_code=2;
   code = "Blink";
}blink_trial;      # Blink screen with a white "Blink Eyes Once." at the center


trial {
   picture {
      text {caption = " "; font_size = 30; font_color = 255, 255, 255;
      };
      x = 0; y = 0;
   };
   port_code=2;
   code = "Interval";
}interval_trial;      # Interval screen with a grey screen display


trial {
   trial_duration = 20000;
      picture {
```

```
    text {caption = "20 Seconds Break."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Break";
}break_trial;     # Break screen with a white "20 Seconds Break." at the center

trial {
  trial_duration = 3000;
    picture {
    text {caption = "Section End"; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "End";
}end_trial;     # screen with a white "Section End" at the center

array {
  bitmap {filename = "A1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternA1";}pattern1;
  bitmap {filename = "A2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternA2";};
  bitmap {filename = "B1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternB1";};
  bitmap {filename = "B2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternB2";};
  bitmap {filename = "C1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternC1";};
  bitmap {filename = "C2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternC2";};
  bitmap {filename = "D1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternD1";};
  bitmap {filename = "D2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternD2";};
  bitmap {filename = "E1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternE1";};
  bitmap {filename = "E2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternE2";};
  bitmap {filename = "F1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternF1";};
  bitmap {filename = "F2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternF2";};
  bitmap {filename = "G1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternG1";};
  bitmap {filename = "G2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternG2";};
  bitmap {filename = "H1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternH1";};
```

```
  bitmap {filename = "H2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternH2";};
  bitmap {filename = "I1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternI1";};
  bitmap {filename = "I2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternI2";};
  bitmap {filename = "J1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternJ1";};
  bitmap {filename = "J2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternJ2";};
}patterns;


trial {
       stimulus_event {
         picture { bitmap pattern1; x = 0; y = 0;
                  } pic;
         duration = 11000;
         port_code=1;
         }event1;
}main_trial;


begin_pcl;
 #pcl
preparation_trial.present();
patterns.shuffle();
loop int i = 1 until i > 5 begin
      eyesclose_trial.present();
      eyesopen_trial.present();
      blink_trial.present();
      interval_trial.set_duration(random(2500,3500));
      interval_trial.present();
      pic.set_part( 1, patterns[i] );
      event1.set_event_code( patterns[i].description() );
      main_trial.present();
        i = i + 1
end;
break_trial.present();
loop int i = 6 until i > 10 begin
      eyesclose_trial.present();
      eyesopen_trial.present();
```

```
      blink_trial.present();
      interval_trial.set_duration(random(2500,3500));
      interval_trial.present();
      pic.set_part( 1, patterns[i] );
      event1.set_event_code( patterns[i].description() );
      main_trial.present();
         i = i + 1
end;
break_trial.present();
loop int i = 11 until i > 15 begin
      eyesclose_trial.present();
      eyesopen_trial.present();
      blink_trial.present();
      interval_trial.set_duration(random(2500,3500));
      interval_trial.present();
      pic.set_part( 1, patterns[i] );
      event1.set_event_code( patterns[i].description() );
      main_trial.present();
       i = i + 1
end;
break_trial.present();
loop int i = 16 until i > 20 begin
      eyesclose_trial.present();
      eyesopen_trial.present();
      blink_trial.present();
      interval_trial.set_duration(random(2500,3500));
      interval_trial.present();
      pic.set_part( 1, patterns[i] );
      event1.set_event_code( patterns[i].description() );
      main_trial.present();
       i = i + 1
end;


end_trial.present();
```

Appendix A.2 A self-written scripts of Presentation scenario for presenting the slides in the second part of the experiment.

```
#header
scenario = "Self-reported Rating Experiment";
default_background_color = 128, 128, 128;
write_codes=true;
pulse_width=20; # default pulse width =5ms
begin;

#SDL
trial {
  trial_duration = 8000;
   picture {
    text {caption = "Preparing..."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Preparation";
}preparation_trial;      # Preparation screen with a white "Preparing..." at the center

trial {
  trial_duration = 8000;
    picture {
    text {caption = "Please rate the next pattern."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Rating";
}rating_trial;      # Rating screen with a white "Please rate the next pattern." at the center

trial {
  trial_duration = 4000;
    picture {
```

```
      text {caption = "Thank You!"; font_size = 30; font_color = 255, 255, 255;
      };
      x = 0; y = 0;
   };
   port_code=2;
   code = "Thanks";
}thanks_trial;      # Thanks screen with a white "Thank You!" at the center

array {
   bitmap {filename = "A1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternA1";}pattern1;
   bitmap {filename = "A2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternA2";};
   bitmap {filename = "B1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternB1";};
   bitmap {filename = "B2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternB2";};
   bitmap {filename = "C1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternC1";};
   bitmap {filename = "C2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternC2";};
   bitmap {filename = "D1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternD1";};
   bitmap {filename = "D2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternD2";};
   bitmap {filename = "E1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternE1";};
   bitmap {filename = "E2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternE2";};
   bitmap {filename = "F1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternF1";};
   bitmap {filename = "F2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternF2";};
   bitmap {filename = "G1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternG1";};
   bitmap {filename = "G2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternG2";};
   bitmap {filename = "H1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternH1";};
   bitmap {filename = "H2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternH2";};
   bitmap {filename = "I1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternI1";};
   bitmap {filename = "I2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternI2";};
   bitmap {filename = "J1.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternJ1";};
   bitmap {filename = "J2.jpg"; width = 1040; scale_factor = scale_to_width; description = "patternJ2";};
}patterns;

trial {
    stimulus_event {
        picture { bitmap pattern1; x = 0; y = 0;
              } pic;
```

```
        duration = 30000;

        port_code=1;

        }event1;

}main_trial;


begin_pcl;


#pcl

preparation_trial.present();


patterns.shuffle();


loop int i = 1 until i > 20 begin

     rating_trial.present();

     pic.set_part( 1, patterns[i] );

     event1.set_event_code( patterns[i].description() );

     main_trial.present();



     i = i + 1

end;


thanks_trial.present();
```

Appendix A.3 A self-written MATLAB script for calculating the power of the Delta (1 - 3 Hz), Theta (4 - 7 Hz), Alpha (8 – 13 Hz), Beta (14 – 30 Hz) and Gamma (30 – 50 Hz) of the EEG signal.

```
%Calculation of participants 5 frequency band powers on 19 electrode
%channels, in both 2s baseline period and 10s patterns viewing period,
%and their subtraction which is the absolute power evoked by the
%pattern viewing. To compute the powers in other pattern conditions by
%changing 'patternA1' to other pattern name.

readdir = 'C:\Documents and
Settings\071210580.BORDERSCOLLEGE\Desktop\Experiment\Experiment with
patterns\Experiment EEGlab Data\10s Patterns View\Clean 10s Pattern
View with 2s baseline\';

datasets = dir([readdir '*.set']);



 band = [1,3,4,7,8,13,14,30,30,50];
 bandname = {'delta','theta','alpha','beta','gamma'};
 f = 1;
 b = 1;

for p = 1:5
    n = 0;
    m = 1;

     for n_file = 1:length(datasets)

         [ALLEEG EEG CURRENTSET ALLCOM] = eeglab;
         EEG =
pop_loadset('filename',datasets(n_file).name,'filepath',readdir);
         [ALLEEG, EEG, CURRENTSET] = eeg_store( ALLEEG, EEG, 0 );
         eeglab redraw;

         subjects(m,:)= EEG.filename;
         m = m+1;

         for n_Epoch = 1:EEG.trials

             if  strcmpi(EEG.event(1,n_Epoch).type,'patternA1')

                 for x = 1:EEG.nbchan
                     k = x;
                     [spectra1,freqs1] =
spectopo(EEG.data(x,1:400,n_Epoch),0,EEG.srate,'winsize',400,'overlap'
,200,'plot','off');

                     [spectra2,freqs2] =
spectopo(EEG.data(x,401:2400,n_Epoch),0,EEG.srate,'winsize',400,'overl
ap',200,'plot','off');





% EEG.data(x,1:400,n_Epoch) means the study data is the first 2
```

```
seconds in each pattern viewing epoch, which is baseline period.

% EEG.data(x,401:2400,n_Epoch) means the study data is in the 3rd
second to the 12th seconds in each pattern viewing epoch, which is the
pattern viewing period.

% use function spectopo to compute the spectral power of each
frequency.

% window size is 2s=400 data point, and overlap 1s = 200 data points.

% outup variable 'spectra' shows power and 'freqs' defines the
%frequency.



                     a1 = mean(spectra1(1,find(freqs1 >= band(b) &
freqs1 <= band(b+1))));

                     a2 = mean(spectra2(1,find(freqs2 >= band(b) &
freqs2 <= band(b+1))));


                     power(n+1,k)= a2-a1;
                 end
             end
         end
         n = n+1;
    end

  frequencyname = bandname(1,p);
  patternA1_freqpower(p,:)=
struct('frequency',frequencyname,'subjects_order',subjects,'subjects_c
hanelspower',power);
  b = b+2;
end
```

Appendix A.4 A self-written MATLAB script for detecting the R waves in the ECG signal during the epoch of 2 second before the pattern onset to 10 second after.

```
% MATLAB script for detecting the R wave waves in the ECG signal
% during the epoch of 2s before the pattern onset to 10s after.
% “sig” is the imported ECG signal, “k” is sampling point inside the
%signal, and “700” is variable among participants, which is the
%minimum potential of the R wave.
% The output of the script is total beat count and a data of R wave

n = 0;
beat_count = 0;
for k=2:length(sig)-1
   if(sig(k) > sig(k-1) & sig(k) > sig(k+1) & sig(k) > 700)
        k
        disp('prominant peak found');
        beat_count = beat_count + 1;
        data(n+1,1)= k;
        n = n+1;
   end

end
```

Appendix A.5 Differences of 20 participants' average Delta power between Repeating and Non-repeating patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
-2.90897	-0.35262	-1.84966	0.365199	-0.64449	0.231829	-0.76939	-0.61941	-2.56852	-1.86601	-2.68781	-1.20045	-0.9938	-0.4884	-2.04466	-2.69819	0.441726	-1.61424	-1.36483
-0.56254	-2.9438	-1.43406	-2.82563	-1.10851	-4.1442	-0.47388	-2.77389	-2.29755	-3.53485	-0.4006	-0.88549	-0.81751	-1.30172	-2.47414	-1.23553	-3.52052	-3.58372	-0.26958
3.741745	2.112611	3.146328	2.590542	*	1.374846	0.659186	2.112528	-1.75789	3.874395	3.532085	2.863523	3.365934	*	-0.7382	1.370248	0.613869	1.127429	1.246229
-1.61983	-0.95281	-0.24964	-0.02431	0.611611	0.120439	-2.75945	0.312302	-0.52879	-0.67882	-0.23617	-0.18381	-0.96339	-1.27302	-0.14267	-1.66979	0.333209	0.983213	-0.34721
-0.07916	2.739773	-0.36486	0.604428	0.60118	-0.0631	-0.9406	0.104384	1.629225	1.882456	0.917929	1.971462	-1.37862	-0.8873	-0.95877	0.270613	0.922964	0.510707	1.605747
1.606456	1.848043	0.971793	2.243648	0.759203	2.65554	4.40884	-0.71164	2.285039	0.985637	2.580205	3.022482	3.887251	*	2.785233	2.080876	0.89982	0.517274	3.383094
-2.54473	-0.67914	-0.76435	-1.5681	-0.53949	-0.96146	0.229165	-0.39779	2.455869	-1.7627	-1.32801	-0.54248	-0.97547	-1.6215	0.792289	1.370248	0.305195	-1.85123	-4.53587
1.70038	1.828238	1.120806	2.690153	1.431288	2.519599	3.46938	0.537268	3.00566	1.977819	1.914855	2.07895	2.764662	*	3.2159	0.457395	2.871499	1.867082	1.684916
0.473857	0.380585	1.327103	-0.03313	1.242814	-0.38976	1.674642	-0.18612	0.818899	0.051756	1.837956	0.799832	0.747349	-1.01262	-0.21415	1.240674	-0.86191	-1.47217	1.959742
-6.62129	0.304744	-5.13112	0.36917	0.690907	0.557735	-2.04701	3.522125	-1.65549	-3.02818	-2.38356	-1.19936	-1.9913	-0.29655	1.088482	-0.75464	0.453058	-0.42777	-1.9149
1.059065	0.222025	1.684695	0.496656	1.363382	1.602603	1.20686	1.27349	1.392118	2.023067	1.797519	0.369064	1.266618	0.021393	0.275901	2.394474	1.15909	0.638842	0.513512
0.69005	2.111867	-1.92408	1.106757	-0.35508	-0.65827	1.683103	0.916448	-2.59824	0.255856	0.412834	-0.35661	-0.08515	-1.35017	-0.17088	1.268901	0.111552	-0.00901	1.429677
0.983759	4.02362	0.978721	1.978756	2.150711	1.350942	3.039874	2.243475	1.329612	4.829156	3.817591	2.909199	3.875508	1.236718	1.272611	2.168569	2.666473	4.084629	3.419881
0.584365	0.236185	-1.99417	0.043415	0.650827	0.094151	1.462567	-0.36983	1.28612	0.354469	0.528315	0.330863	-0.21498	0.468261	0.284055	0.190223	-0.06392	0.321378	2.513846
-0.58107	-0.93795	-2.03131	0.365991	-0.40147	1.93857	2.124807	0.109383	3.691934	-0.50395	-0.27345	0.988257	1.817983	2.326788	3.618316	-4.49206	1.182629	0.185143	1.870076
1.954622	1.979257	1.365464	2.632368	-0.45857	2.472606	2.617763	-2.43178	1.249442	1.832858	1.961949	2.85371	2.743142	*	2.132605	2.489289	-0.70648	-2.74408	1.836238
-4.55972	-3.43879	-1.20962	-1.98519	-0.1846	-0.9656	0.13691	0.864917	2.27214	-2.29772	-1.9982	-3.20272	-1.47315	-1.87723	-0.79277	-0.177	-1.02796	0.601726	1.62268
2.738997	-1.94032	2.37036	-0.78655	-1.25938	-1.44474	-0.43951	-2.52698	2.710871	0.353017	1.522385	0.140034	-0.25548	0.429882	0.133833	1.038172	-0.33127	0.082896	-0.60946
-2.17587	-0.89192	-0.54473	-1.70113	-0.42453	-2.2385	-0.86962	0.382333	-0.22477	-0.87515	-1.76522	-0.71223	-1.86145	-1.33734	-1.41388	-2.36502	-0.83807	-1.91163	-0.90916
-3.88098	-1.39723	-1.57146	-0.84869	-0.85879	-0.41107	-1.53381	-1.87472	-3.98076	-0.98273	-0.93718	-1.31595	-2.19248	-1.10336	-1.48894	-1.55825	-1.50997	-2.15597	-3.40603

* Odd sample was excluded for the normal distribution of the data.

Appendix A.6 Differences of 20 participants' average Theta power between Repeating and Non-repeating patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
2.236536	2.460299	-1.16508	2.67209	1.384441	2.412495	3.052555	1.649371	1.839724	1.090745	2.301485	2.576072	3.016332	*	1.979849	-0.67704	2.009267	0.153931	-1.88887
0.754969	-0.51722	0.207057	0.237566	0.306303	0.103215	-0.34885	-1.98895	-2.74776	-1.33224	-0.52548	0.806752	0.060171	0.298687	-0.27417	-0.79776	-0.78683	-1.00445	0.33491
0.58671	1.64791	0.708389	0.708654	0.691324	1.074655	2.568262	-0.03922	-0.11763	0.869014	1.008265	1.343555	0.952777	1.434547	2.559628	1.936616	1.85466	-0.42425	3.713778
1.861984	1.001224	2.39567	0.885547	0.714411	1.460073	1.050248	1.647586	4.753358	0.884749	0.864037	0.913961	1.829271	1.756456	2.2815	1.106374	1.209746	1.789274	1.968332
-0.12652	0.996767	-0.92387	0.102787	-0.37596	-1.78143	0.832692	-3.12617	-2.10621	-0.38942	-0.7376	-1.1893	0.116739	-0.28314	0.667725	-0.85637	-1.36839	-1.21477	1.509583
1.217162	0.348048	1.61868	0.743543	-0.53718	-0.74488	2.681107	-1.60092	1.333027	1.710609	1.727026	1.149739	2.557719	0.296358	0.538317	*	-2.31658	-1.29322	2.738378
0.66887	-1.49571	1.80286	-2.05599	-0.12127	-1.08577	-0.15056	0.207761	-0.23187	-0.14295	0.922112	-0.00659	-0.74193	-1.13252	-0.57702	0.52102	-0.68339	-0.17048	-0.59468
-2.54581	-2.93761	-2.88455	-4.0096	-3.44895	-2.89384	-1.25792	-3.66933	0.895359	-2.38928	-1.8677	-2.8375	-1.69403	-1.65709	-0.51967	-1.01121	-1.64992	-0.44683	0.697174
-1.6519	1.750959	-2.23081	0.381425	1.947358	-0.04091	-0.20071	2.220673	-2.34354	2.322696	-0.20523	0.059811	-1.1354	0.624065	0.397727	-1.88917	0.670662	1.942251	1.132753
-0.45413	-0.37966	-2.66408	-0.15646	0.359722	-0.80486	0.222282	-0.24597	-0.15513	-1.54301	-0.4909	-0.78423	-0.11096	-0.2287	0.256506	-0.82873	0.314759	1.298384	-2.06529
0.150177	-1.39963	-0.27349	-0.7318	-0.22009	-0.4321	1.410573	1.951732	2.670098	-0.37569	-0.13229	0.010231	-0.04756	-0.33425	1.858756	-1.20328	0.905782	3.45012	1.027542
0.758027	-0.44471	-0.91837	-0.62093	-0.61985	-0.60458	-1.65902	-1.02568	-1.38983	-1.29044	0.231445	0.353308	-0.81784	-0.08996	-1.37214	1.777269	-2.15637	-2.40055	-0.13833
3.185226	-2.8283	0.621665	-1.1364	-1.54888	-0.83615	0.359653	-0.05146	1.655737	0.942548	0.194523	0.285164	0.409052	-0.35548	-0.88561	0.737333	-0.65555	-1.70741	-1.02601
0.878105	-1.62505	-2.40257	-1.4971	-1.19678	-1.57527	-1.50731	-0.9731	-2.07909	-1.20265	0.526854	-0.58693	-0.52392	-0.8737	-2.06693	-0.93852	-1.91769	-1.12838	1.377816
-0.98708	-0.99128	0.133736	-1.11585	-1.91573	-2.23821	-1.01952	-1.04414	1.269067	-1.90293	-0.9734	-1.0372	-0.35578	-1.30451	-0.70743	-0.63895	-1.28973	1.023465	2.118746
1.551814	3.617128	-0.0048	2.339767	2.646389	3.294906	-0.17754	2.643062	0.805386	1.915878	-0.47075	1.320498	0.255221	0.46494	-0.36722	-0.77544	2.314539	1.227358	-1.2668
0.692198	-0.99239	1.743119	-0.60234	-1.48126	1.542542	0.229746	0.639129	0.30973	0.706581	1.262712	0.18031	1.325453	2.910313	2.366476	0.95038	1.675608	1.769931	0.764359
-0.68595	-4.3449	0.479894	-1.53187	-1.94296	-2.31049	-0.07416	-1.24388	-0.26522	-1.18598	0.280371	-0.01988	0.393912	-0.65262	-0.78642	0.342895	-1.26675	0.530274	-0.99864
-1.50008	0.690165	-2.28542	0.529158	-0.65782	0.367824	0.053749	-0.57995	-0.02176	-0.29186	0.842619	0.829976	0.816752	0.469389	-0.80116	-0.58442	-1.56181	-1.59544	-0.79858
-1.47456	-3.17974	-1.70355	-1.96134	-3.07316	-0.89949	2.602404	-3.11389	1.422523	-3.78972	0.626323	-2.47223	2.496153	-1.04807	-1.79937	-0.43504	-2.21875	-2.47222	-1.15998

* Odd sample was excluded for the normal distribution of the data.

Appendix A.7 Differences of 20 participants' average Alpha power between Repeating and Non-repeating patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
-1.06462	0.805758	-1.64556	1.093443	0.643852	1.152796	0.547308	0.25528	1.269234	-0.17285	-1.31778	-0.22313	-0.30835	0.286296	0.121584	-0.5117	0.838384	1.235158	-0.4534
0.182414	0.234262	1.226225	0.099641	-1.38254	-0.24531	-1.00156	-1.9737	-0.1978	0.467132	-0.97982	0.766359	-1.43075	-0.57323	-0.65314	0.779184	-1.4504	-2.54405	-0.00792
3.403985	2.406668	2.597755	1.258344	1.142904	0.442519	*	0.350006	1.177275	1.857816	2.176348	1.805894	1.984892	1.198204	1.630049	2.642123	0.271255	0.034483	1.34965
0.911774	0.914938	0.712753	1.466662	0.787218	1.649398	0.030373	2.035037	1.231133	2.110123	1.231152	1.290549	0.751123	0.180834	-1.35755	0.619701	0.7071	0.957472	-0.71049
-0.21239	0.187151	0.378184	1.770197	3.368489	0.545362	0.855464	2.803636	0.73231	-1.05296	0.32714	-1.36584	0.378031	0.845279	1.930691	0.693922	0.565611	0.985452	0.868432
-0.88013	-1.90879	0.76618	1.358452	0.444533	1.68304	1.246766	-0.50726	-1.00148	-0.18532	0.089314	0.320165	-0.23193	0.911797	1.290732	-0.19779	0.665807	-1.81457	1.154803
-0.07999	-1.54121	0.397139	-1.96943	-0.22393	-1.74376	*	-0.05657	-0.51291	0.369143	-1.05653	-0.97935	-2.59076	-1.96762	-2.04846	-0.54253	-0.95723	1.004965	-2.03591
-0.827	2.732753	-0.8489	2.444416	2.740289	1.120926	-0.56392	3.052414	-0.81855	-1.76704	0.062468	0.160397	0.254997	-0.09633	-0.13056	-0.40309	1.633186	2.367398	0.159203
1.548832	0.559957	0.870526	1.145449	0.522793	0.578944	0.077501	-0.02922	-0.93431	1.076022	0.278933	0.861617	-0.12084	0.089635	0.757407	-0.50559	0.058465	0.549377	-0.54015
-0.82707	-0.50535	-1.71617	-0.42312	-0.2575	0.01662	-1.09988	2.135313	-1.93557	-0.9347	-0.40354	-0.60061	-0.92424	-0.81778	-0.07352	-0.99854	0.89124	1.250365	-0.72289
-1.20037	-1.51415	-1.83652	-0.5612	-0.68652	-0.62043	-1.13084	-0.03659	-0.69563	-1.52166	-1.97611	-0.67312	-1.27961	-1.6088	-0.61947	-1.35391	-0.00562	-0.40351	-1.02221
-3.02552	-2.42849	-0.41513	-1.87014	-1.98574	-1.91289	-1.13331	-1.11693	-0.02246	-2.06316	-0.53292	-1.86125	-1.62642	-1.87734	-1.43745	-0.28176	-1.41617	-0.094	-1.47524
0.136517	-0.59052	-0.82028	-0.84799	-0.69182	-1.06643	-0.70347	-0.86482	0.017265	-0.4783	-0.72083	-0.56937	-1.93253	-0.02838	-1.45319	-0.79057	-1.5641	-1.00515	0.316295
0.70818	0.206123	-0.57643	-0.24559	-1.78408	-0.69436	-0.89698	-3.22093	-2.0729	0.264341	-0.27846	0.10616	-1.3492	-1.02658	-1.45174	-2.5591	-1.17687	-1.85766	0.677434
-0.64641	-1.02726	-1.1253	-0.79519	0.302293	0.12461	0.211799	2.223535	-1.62573	-1.85635	-0.66883	0.084014	-0.48742	1.050112	0.765438	0.495557	0.415223	-1.53422	-0.60775
0.840586	-0.44266	1.536735	0.216504	-1.10569	0.613171	0.457377	-0.1981	0.001176	-0.35068	1.253534	-0.06379	0.128452	-0.38487	-0.46222	0.99503	0.472467	0.529794	0.449336
-1.44264	1.117748	-2.13939	1.128882	-0.08811	0.014353	-0.55744	-0.71357	0.615112	0.431408	-0.79383	0.171048	-0.93041	-0.90455	-0.04794	-1.74554	-0.7969	-1.13274	-0.08652
1.309124	-0.05824	0.615076	0.208326	0.648351	0.11716	0.382057	0.909022	-0.92335	0.995971	0.77748	0.570804	0.427579	0.67964	1.707417	0.13132	1.194952	0.484515	-0.52146
-0.77982	0.120451	-0.21261	1.961162	0.529477	1.015982	-0.66272	-0.37992	0.031403	-0.11616	-0.64748	1.106966	-0.49055	0.837492	0.173549	1.014804	0.394389	-0.46041	-0.09467
-2.27882	-2.03798	-2.64229	-3.44898	-1.67068	-0.62045	-0.89933	-1.60156	-0.37063	-3.80741	-1.25242	-1.80443	-1.10984	-0.93098	-0.36257	-2.33571	0.062955	-1.04376	-1.38865

* Odd sample was excluded for the normal distribution of the data.

Appendix A.8 Differences of 20 participants' average Beta power between Repeating and Non-repeating patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
-1.03848	0.630043	-0.84937	-0.12201	0.019658	-0.16647	0.073098	-0.06913	-0.6192	0.002922	-0.56687	-0.59784	0.07239	-0.32215	0.16691	-0.40427	0.107083	-0.13346	0.078225
-0.4799	-0.54424	-1.23215	-0.47186	-0.8153	-0.96059	-0.81651	-1.66673	-0.11229	-1.06809	-1.02032	-0.71569	-1.07875	-1.35194	0.121249	-0.8404	-1.20252	-1.56704	-0.04715
-0.88011	-0.27576	-0.81555	-0.56621	0.875678	0.029763	-1.06381	-0.45637	-1.66754	-0.63321	-1.11623	-0.64623	-0.67237	-0.49334	-0.51948	0.067872	-0.73812	-1.06023	-0.19986
-0.76949	-1.03144	-0.90704	-0.04329	-0.546	-0.29904	-0.56079	-0.03519	-0.51787	-0.18558	-0.41893	0.615917	-0.52257	-0.08114	-0.40169	-0.36928	-0.18441	-0.82697	-0.78532
*	0.930165	0.638028	1.166113	0.87192	1.343805	0.826598	2.518877	*	0.546114	1.859116	0.514495	1.461941	1.378247	*	0.357579	2.678137	1.826459	*
0.886793	-0.92782	0.76176	-0.21962	-1.44876	0.757517	0.441518	-1.19682	0.659406	0.203385	1.023445	0.941666	0.133342	0.308542	0.405763	0.942161	0.504035	0.034349	0.615272
-0.5881	0.889602	1.354297	1.155473	0.520902	0.13823	0.22115	0.981258	0.150794	-1.06006	-0.16771	-0.26506	0.006237	-0.26545	-0.68523	-0.10874	0.322178	0.557431	-0.87035
0.184447	-0.021	0.494589	-0.28493	-0.01609	-0.76867	0.536197	0.624203	-0.85234	-1.44925	0.53524	0.809738	0.224228	-0.05921	0.146756	1.195135	0.107817	1.82946	0.925533
0.044447	1.357623	1.20497	1.139081	1.392725	1.565176	0.834896	1.058552	0.314584	0.496758	1.215218	0.530398	0.638014	1.225923	*	0.542072	1.393818	1.241383	0.120922
-0.42534	0.211284	0.487263	0.458057	-0.99229	0.506612	-0.16846	-0.91712	-0.55128	0.41834	0.352789	0.494992	-0.06402	-0.15875	0.332347	0.311398	-0.22442	-0.04786	0.681758
0.432308	-0.24673	-0.83196	0.758455	0.427561	0.552355	-0.18364	0.069734	-0.28544	0.572395	-0.41374	0.539812	-0.63814	-0.4427	-0.38148	-1.52292	0.630107	0.667029	-0.89532
1.799343	0.705957	0.282693	0.289829	-0.30139	0.463433	-1.83698	0.094818	0.371223	1.025499	1.177613	1.778995	0.694047	0.779205	0.3498	-0.78834	-0.4444	-0.16656	-0.4827
0.649962	-0.6113	-1.18162	-0.96858	-0.0651	-1.66547	0.588356	-0.99459	-0.17293	-0.00787	1.162142	-0.08573	-0.76435	-0.60702	-0.50659	-0.48393	-1.33063	-0.86233	-0.48482
0.622498	0.158031	1.259476	0.349973	-0.74943	0.620437	0.885849	-0.82616	-0.32269	-0.64907	1.072688	1.154047	0.697103	1.594577	0.492302	0.33959	-0.0834	-0.35655	-0.30559
0.255746	0.572466	0.565442	1.351147	0.544084	1.891765	1.470795	0.513695	0.485886	0.377069	0.578331	0.855117	1.003098	1.668118	*	0.358082	2.362262	0.660064	-0.05138
-0.49355	-0.46425	-0.53678	-0.29958	-0.31006	-0.45704	-0.03236	-0.05603	0.340001	-1.24731	-0.25651	-0.83831	0.546513	-0.54899	-0.7818	-0.34292	-0.26764	-0.43701	-0.08309
-0.33355	-0.14054	-1.09419	-0.00525	-0.19098	-0.21518	-0.29385	-0.88612	0.346796	0.049827	-0.60871	0.020757	-0.6269	-0.64644	0.123646	-0.94715	-0.20793	-0.32698	-0.66086
-0.34794	-1.35145	0.257313	-1.45946	-0.3239	-0.72101	-0.8729	-1.45816	0.158679	-0.67192	-0.49043	-1.5521	-1.25293	-1.56394	-0.4361	-1.25424	-0.59484	-1.16744	-0.27208
-0.9347	-0.86429	-0.9983	-2.08311	-1.10517	-1.7177	-2.43722	-1.19022	-0.71631	-0.47574	-1.36916	-1.35508	-1.53035	-1.74278	-0.44312	-0.74709	-1.72168	-1.31079	*
-0.17924	0.565564	-0.52999	0.097803	0.177784	0.066552	0.070552	0.24618	1.875587	0.67064	0.906753	0.306371	-0.23332	0.47214	*	-0.20485	0.985926	1.137397	0.6482

* Odd sample was excluded for the normal distribution of the data.

Appendix A.9 Differences of 20 participants' average Gamma power between Repeating and Non-repeating patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
-0.91872	-0.90003	-0.24698	-0.28314	-0.34485	-0.3372	-0.02843	0.524285	-0.25482	0.278738	-0.86186	-0.62942	-0.34168	-0.64828	-0.53662	-0.14888	-0.04316	0.485842	-0.71926
-0.27492	-0.83663	0.029619	-0.65178	-1.08664	-0.6752	0.567542	-1.23028	-1.34831	-0.65546	0.147159	-0.05898	0.934931	0.086864	0.292324	0.479019	-0.9929	-1.81038	-0.39389
1.202488	-0.04536	0.307525	-0.21643	0.297915	0.184297	0.825436	-0.20896	0.1717	0.375831	0.045046	0.354306	-0.15661	0.212081	0.036874	0.281646	-0.4635	0.262863	-0.14429
0.515965	0.226479	0.445484	0.121822	-0.30165	-0.02983	0.125626	-0.29563	0.965025	0.297309	-0.1255	-0.00221	0.049299	0.455257	-0.33808	0.722363	-0.40088	-0.19734	0.099458
1.792697	0.202517	0.674893	0.546259	0.756217	0.695306	*	1.493796	2.220818	0.881415	0.550812	0.149943	0.426231	0.807398	*	0.108413	*	0.915567	*
0.341352	0.143816	-0.41188	0.212125	-0.07812	0.292088	0.380637	-0.79683	-0.29793	0.939569	1.46595	1.422025	1.098209	-0.02568	0.292822	1.718896	-0.22096	-0.34941	0.705171
0.48066	0.600178	0.913325	0.606742	-0.38766	1.255879	0.357909	0.295931	0.765165	0.337305	0.596073	0.507272	-0.31647	0.802814	0.601522	0.296338	0.35528	0.700976	0.262368
0.16232	0.395632	-1.15057	-0.08315	0.418155	-0.60141	0.833112	-0.19468	-1.12013	-0.81126	-0.03629	-0.46282	-0.03017	-0.14714	-0.57944	0.237697	-0.69997	-0.78865	-0.09874
0.22604	-0.42056	-0.79419	-0.28372	-0.95207	-0.40801	-0.34378	-1.23316	-1.31395	-0.22557	-0.73024	-0.89246	-0.62514	-0.3693	-0.99777	0.416826	-0.91086	-0.2931	-0.39686
*	-0.83581	-0.47039	-0.82464	-1.3419	-1.09103	-0.9065	-1.44127	-1.35868	0.354925	-0.87174	0.019409	-1.17414	-0.55718	-0.13502	-0.75601	-1.22808	-0.60912	-0.90709
0.423514	0.462168	0.403772	0.526158	0.65913	0.669686	-0.10427	0.316536	0.22308	1.701275	1.201868	1.245603	0.760753	0.293871	-0.07763	1.471594	0.438422	0.337609	0.367094
0.865271	0.054929	-0.31537	-0.17206	-0.69249	0.021606	0.476493	-0.44096	1.157275	0.423535	0.132527	-0.08401	-0.49218	-0.17111	-1.16079	0.177815	-0.6539	-0.31965	0.072038
1.197013	-0.81113	0.95261	-0.69863	-0.13377	-0.7471	0.052751	-0.69943	0.082175	0.212435	1.41455	0.12895	-0.81755	0.009117	-0.20308	1.27723	-0.95872	-1.11261	1.008076
0.902504	-0.08673	0.712728	-0.10073	-0.05788	-0.45911	1.786056	-0.27312	0.710708	-0.34098	0.630074	-0.17299	0.054211	-0.52819	-0.01269	0.053156	-0.44473	-0.19589	0.183584
0.533956	0.132083	1.272093	0.580036	0.527088	1.224146	1.623554	0.385471	0.788848	0.515485	0.912128	0.642667	1.509851	1.363802	*	0.518066	*	0.82619	0.789988
0.590334	0.674661	0.413547	0.02082	-0.61775	-0.72935	0.346691	-0.21611	0.3475	1.299184	0.333021	0.109723	-0.16601	-1.11417	-0.96444	0.501983	-0.80068	-0.92181	0.418788
0.306045	-1.17651	0.010141	-0.48514	-0.71575	-0.19653	-0.06519	-0.68168	0.560743	-0.72613	-0.08587	0.077044	0.484406	0.075151	-0.1898	0.183666	-0.57587	0.080182	0.250508
-1.11267	-0.41049	-1.01216	-0.9554	-0.39403	-0.01374	-0.60665	-0.32323	0.197448	-0.86516	-0.74095	-0.55309	-0.43241	-0.25075	-0.44037	0.15312	-0.01389	0.111152	-1.41349
0.056078	-0.20037	-1.0969	-0.37509	-0.36759	-1.00875	-1.01738	-0.85813	0.80693	-0.2707	0.133336	-0.27122	-0.91016	-1.07146	-0.38243	0.560965	-0.43161	-0.86658	0.684813
1.557918	-0.26077	1.704166	-0.42731	-0.3013	-0.74714	0.573973	-0.87152	0.958218	0.358165	1.036119	0.655734	0.461397	0.090916	*	1.185484	-0.5238	0.590541	1.742554

* Odd sample was excluded for the normal distribution of the data.

Appendix A.10 20 participants' Frontal Alpha Asymmetry index for Repeating patterns.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
0.05147	-0.0474	0.09886
1.83496	1.70934	0.12562
3.00735	2.8983	0.10904
2.01708	0.45612	1.56097
2.41697	2.47603	-0.05905
1.10665	0.842	0.26465
0.68643	-0.53871	1.22514
2.53884	2.14952	0.38932
1.50043	0.33865	1.16178
0.65111	1.08894	-0.43783
0.52349	0.52539	-0.0019
0.5279	0.41079	0.11712
1.15511	2.16693	-1.01182
1.67556	2.0448	-0.36924
1.18295	1.31327	-0.13032
2.41022	1.29925	1.11097
0.04694	-0.17037	0.21731
3.32295	2.7294	0.59355
2.46054	1.79512	0.66542
-0.58656	-0.05349	-0.53307

Appendix A.11 20 participants' Frontal Alpha Asymmetry index for Non- repeating patterns.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
1.39412	0.09187	1.30225
1.69202	1.78611	-0.09408
0.28132	0.89541	-0.61409
1.06519	0.47626	0.58893
2.25266	1.67009	0.58257
1.11486	0.1074	1.00746
0.93289	1.50908	-0.57619
3.07665	2.4188	0.65785
0.601	0.6614	-0.0604
1.63337	2.02937	-0.396
2.19449	1.69437	0.50012
1.85243	1.37422	0.47821
1.62331	2.55951	-0.9362
1.72446	2.97101	-1.24655
1.99646	1.28007	0.71639
1.19993	0.66534	0.5346
1.50556	0.62613	0.87943
2.42239	2.73209	-0.3097
3.00718	1.70932	1.29786
1.47128	1.48774	-0.01646

Appendix A.12 20 participants' average heart rate changes (bpm) on each second window when responding to Repeating patterns.

Participants \ Time Window	1s	2s	3s	4s	5s	6s	7s	8s	9s	10s
1	3.0378	4.01255	2.79141	1.22254	0.61034	-0.7517	-1.5616	-0.12673	0.41165	-0.42127
2	-0.4635	-0.70466	-1.01451	-1.41891	-1.89179	-2.66937	-3.36021	-3.92793	-4.27791	-4.18274
3	-1.01876	1.90736	1.91389	-0.23683	-1.59152	-2.4401	-3.56318	-0.66906	0.93864	-0.18407
4	0.67336	0.38856	0.61156	-0.5553	-1.10787	-1.23195	-1.23531	-1.21566	-0.78736	-0.27589
5	1.47785	0.07206	0.30023	-1.35568	-1.41266	-2.04545	-2.75661	-2.74681	-2.63726	-2.81598
6	-2.10034	-4.55379	-2.73505	-2.63435	-3.17909	-0.41612	-0.92068	-1.98067	-1.12768	-2.51199
7	-0.9438	-6.631	-6.9709	-8.1216	-7.2665	-7.7417	-11.7292	-11.3165	-10.7583	-10.3739
8	-1.55489	-1.98701	-1.01306	-2.16779	-3.67253	-3.36483	-1.54633	0.96376	-1.56652	-4.05938
9	0.08102	-0.54679	-1.46421	-2.70844	-2.71713	-2.49119	-2.33714	-2.65439	-3.27279	-3.07921
10	-2.77363	-3.56135	-3.1698	-2.44516	-1.96791	-1.59159	-1.00728	-1.0203	-0.56392	-0.16161
11	-1.64732	-1.19214	-1.21967	-2.05865	-3.22083	-4.54707	-4.32566	-4.336	-4.23548	-3.52632
12	0.17178	0.13207	1.86624	1.56406	0.36056	0.34942	0.60258	0.71517	0.57516	0.45355
13	-2.43025	-0.87157	-2.23412	-3.65054	-4.0413	-4.53687	-6.15363	-5.2888	-6.72338	-8.80323
14	-0.56707	-0.40498	2.44332	2.55525	0.41091	-0.49842	-1.453	-2.8229	-1.42481	-0.66729
15	-1.8053	-0.2148	-3.1615	0.4649	-8.8154	-8.789	-6.5602	-13.5054	-14.6259	-11.8555
16	-2.03019	-2.27127	-1.75621	-0.67473	-1.94552	-3.47435	-3.81184	-3.81373	-4.86109	-5.32171
17	-1.6256	-3.23749	-3.23411	-4.34173	-5.65569	-7.21257	-7.15763	-5.77112	-6.25377	-5.90796
18	0.93898	5.80965	0.53346	1.14875	-5.98945	-0.30184	1.74378	-0.78989	0.16435	-0.27543
19	-7.2374	-9.4665	-9.6417	-10.0965	-10.6589	-11.2127	-10.7726	-11.7713	-12.3821	-12.1616
20	0.26205	0.00081	0.37257	-0.1062	-1.03489	-0.91647	-0.26581	-0.05468	-0.52075	-1.54267

Appendix A.13 20 participants' average heart rate changes (bpm) on each second window when responding to Non-repeating patterns.

Time Window / Participants	1s	2s	3s	4s	5s	6s	7s	8s	9s	10s
1	2.46923	3.58013	2.80552	1.57398	0.56523	-0.19857	-0.88452	0.09014	-0.68206	-1.12483
2	-0.90269	-0.73654	-1.28372	-1.58865	-1.54273	-1.8816	-2.12529	-2.31955	-2.77439	-2.47487
3	-0.48934	-0.44194	-1.95314	-1.80935	-1.04748	3.27472	-0.40161	0.63696	0.86164	-1.6846
4	0.66255	-0.28219	-0.64269	-0.74138	-0.26031	-0.42156	0.50363	1.58042	2.04236	2.38627
5	-1.11622	-0.59282	-2.80671	-2.47281	-2.34194	-2.5622	-3.7747	-4.27229	-3.61579	-3.86606
6	-0.7591	-4.07571	-1.28178	-0.80012	-1.79341	0.27099	-0.95166	-0.82232	0.31423	-1.45195
7	-4.2587	-7.2885	-8.9503	-12.1871	-12.6273	-8.9025	-6.9732	-4.6781	-3.3058	-3.5783
8	-0.50695	-0.9407	-1.80445	-3.25804	-3.27825	-3.91788	-2.63093	-2.44671	-1.42091	-0.82764
9	-1.32813	-2.83688	-3.56213	-3.89676	-4.51042	-5.4545	-6.2717	-5.84447	-4.72358	-3.97326
10	-2.03055	-3.19463	-3.92201	-3.22483	-2.16132	-1.40528	-1.50306	-0.70558	-0.10281	0.05274
11	-1.21922	-1.05144	-0.98568	-1.30477	-1.63288	-1.97817	-2.19554	-1.73174	-1.25253	-1.15397
12	-3.65115	-1.5645	-0.24281	0.19652	-1.50231	-0.17955	-4.82237	-2.0714	-0.78792	-1.2603
13	-3.71832	-3.92027	-3.49223	-4.39409	-4.8399	-2.52432	-2.66133	-3.78882	-4.1296	-5.13141
14	-2.78683	-1.66321	0.20267	-0.9612	-2.13968	-0.62874	0.21774	-1.26264	-1.81779	-0.3942
15	-2.9829	2.02222	4.84615	-0.96879	0.74026	4.29236	-1.98555	-2.31485	2.04171	0.47885
16	-3.73171	-4.92956	-3.45399	-4.72622	-7.00973	-8.37125	-7.3267	-7.13894	-7.57484	-6.82208
17	-3.73006	-4.86074	-5.56506	-8.05444	-7.74888	-3.9405	-1.3324	-1.14795	-2.6099	-4.18768
18	2.65976	3.92609	2.61549	2.16974	2.1267	-0.92505	-3.63384	1.48505	-0.72056	4.71347
19	-5.74527	-6.10621	-7.45629	-6.86326	-7.50536	-6.4379	-6.54979	-7.49202	-9.12775	-9.05408
20	1.23738	0.43044	-0.06267	-0.61365	-0.08399	-0.20417	-1.04735	-0.86371	-1.17428	-1.60833

Appendix A.14 20 participants' differences of heart rate changes (bpm) on each second window when responding to Repeating and Non-repeating patterns.

Time Window / Participants	1s	2s	3s	4s	5s	6s	7s	8s	9s	10s
1	1.019871	1.167184	0.623443	0.755385	-0.41511	-1.17273	-1.15055	-1.77079	-0.45877	-1.53272
2	2.19343	3.306973	2.463969	1.487368	1.373954	1.7128	2.159799	2.434554	1.555314	1.158186
3	-2.34752	-0.58872	-0.85778	-0.56999	0.649643	-0.45006	-1.4906	-1.23757	-2.58973	-3.05455
4	-5.69691	-0.67907	0.088655	-1.32433	-2.74151	0.604815	5.76002	8.01629	*	6.057893
5	1.906589	0.838249	-0.03637	-0.40784	-2.45021	-2.59218	-2.57726	-1.1278	-0.47139	-1.36829
6	0.317824	-0.03152	-0.68512	-1.34594	-1.65485	-1.75022	-1.29341	-0.12585	-0.62984	-2.45218
7	-0.57199	-1.01753	-1.23227	-1.73426	-2.18836	-2.44287	-2.09558	-2.38273	-2.57343	-2.55648
8	2.556598	1.831826	0.713946	-0.07661	0.905523	1.752288	1.309345	0.404791	0.201331	0.308096
9	4.920843	6.437975	4.254805	4.236949	3.81859	6.680479	1.922196	2.049046	2.961203	4.288096
10	0.185881	-1.98779	-3.14055	-4.53798	-4.61214	-4.6783	-6.11436	-5.06798	-3.70085	-3.89638
11	-0.5676	-0.01364	0.71992	0.370748	-0.73776	-1.64193	-3.27208	-3.36687	-3.03092	-3.95832
12	0.094578	-4.19197	*	-1.09256	-8.53728	*	-10.7301	*	*	*
13	-1.77881	-2.01964	-5.50689	-6.10622	-4.33959	-2.16063	-4.35479	-4.63436	-3.67532	-4.52439
14	1.919225	-0.04364	-3.30059	-3.28742	1.784755	5.894874	4.365265	2.434823	2.074015	2.041489
15	1.097786	-2.03257	-0.02788	1.736964	-1.65036	2.563909	6.631178	-0.13343	-1.59926	3.777986
16	0.451013	2.353221	2.24152	3.788054	1.084995	0.315475	0.735481	-0.79997	0.357089	0.892478
17	-2.002	-0.63642	0.160018	0.464244	-0.55921	-1.33735	0.726535	2.241899	0.939344	-0.89447
18	1.019871	1.167184	0.623443	0.755385	-0.41511	-1.17273	-1.15055	-1.77079	-0.45877	-1.53272
19	2.19343	3.306973	2.463969	1.487368	1.373954	1.7128	2.159799	2.434554	1.555314	1.158186
20	-2.34752	-0.58872	-0.85778	-0.56999	0.649643	-0.45006	-1.4906	-1.23757	-2.58973	-3.05455

* Odd sample was excluded for the normal distribution of the data.

Appendix A.15 19 participants' average rating scores on the Valence scale to Repeating and Non-repeating patterns.

Participant	Average Rating Scores on Repeating patterns	Average Rating Scores on Non-repeating patterns	Differences between Repeating patterns and Non-repeating patterns
1	0.375	0.875	-0.500
2	1.375	-0.375	1.750
3	0.875	0.625	0.250
4	2.625	-0.125	2.750
5	0.625	-0.375	1.000
6	0.625	-0.250	0.875
7	0.875	-0.375	1.250
8	0.375	-0.875	1.250
9	1.000	1.250	-0.250
10	0.625	1.500	-0.875
11	0.250	-0.375	0.625
12	-1.375	1.000	-2.375
13	1.625	0.875	0.750
14	1.250	-1.125	2.375
15	0.125	1.000	-0.875
16	-0.375	-1.375	1.000
17	1.750	1.250	0.500
18	1.000	0.750	0.250
19	0.500	0.375	0.125

Appendix A.16 19 participants' average rating scores on the Arousal scale to Repeating and Non-repeating patterns.

Participant	Average Rating Scores on Repeating patterns	Average Rating Scores on Non-repeating patterns	Differences between Repeating and Non-repeating patterns
1	0.500	1.000	-0.500
2	-1.000	0.625	-1.625
3	1.375	0.625	0.750
4	1.125	0.750	0.375
5	0.125	0.125	0.000
6	0.625	-0.500	1.125
7	-0.125	-0.750	0.625
8	0.750	-0.125	0.875
9	-0.750	-0.750	0.000
1o	0.500	1.000	-0.500
11	0.125	0.750	-0.625
12	-0.250	1.750	-2.000
13	-0.625	0.750	-1.375
14	1.875	1.875	0.000
15	0.000	2.000	-2.000
16	-0.500	-1.125	0.625
17	0.750	0.125	0.625
18	1.000	0.750	0.250
19	0.250	0.500	-0.250

Appendix A.17 19 participants' average rating scores on the Likert scale to Repeating and Non-repeating patterns.

Participant	Average Rating Scores on Repeating patterns	Average Rating Scores on Non-repeating patterns	Differences between Repeating and Non-repeating patterns
1	0.375	1.000	1.000
2	1.750	0.250	0.250
3	0.375	1.125	1.125
4	3.000	0.375	0.375
5	0.500	-0.375	-0.375
6	-0.875	0.875	0.875
7	1.000	-0.375	-0.375
8	0.375	-0.625	-0.625
9	1.000	1.125	1.125
10	0.750	1.125	1.125
11	0.250	0.000	0.000
12	-1.625	0.875	0.875
13	1.500	1.000	1.000
14	0.875	-1.375	-1.375
15	0.500	0.500	0.500
16	0.125	-1.375	-1.375
17	1.750	1.375	1.375
18	1.000	0.750	0.750
19	0.875	1.000	1.000

Appendix A.18 Differences of 20 participants' average Delta power between Weak and Intense patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
-0.86876	-2.69013	-2.18148	-3.56569	-2.94648	-3.63022	-0.16828	-2.46966	0.168559	-3.72731	-1.77742	-1.85468	-2.76386	-4.35921	-2.07405	-1.05002	-1.09818	-1.5603	-0.91773
2.965098	4.098109	3.677839	4.6071	3.840957	1.51754	6.066476	4.887256	4.724718	5.904081	3.70822	4.349604	3.229052	2.448921	4.677415	5.227287	4.314595	4.43019	*
-2.72832	-1.08899	-2.52058	-1.87919	-0.50679	-0.22566	-0.73697	0.167151	-0.12578	-0.44213	-0.95326	-1.26764	-0.94019	-2.26461	-0.10748	0.158389	-1.90924	0.340841	-2.7512
-5.71262	-4.08274	-2.11854	-4.68485	-1.59659	-4.29009	-4.03778	-2.95104	-1.0065	-4.96708	-4.12804	-5.20734	-4.46072	-4.12315	-3.93518	-2.49215	-4.77381	-1.86782	0.511502
-2.14445	-2.30946	-1.86681	-2.33774	-2.2668	-1.4479	-0.24571	-1.53617	-3.35427	-4.57859	-2.56408	-3.43856	-2.16431	-2.25094	-0.48658	0.64782	-2.22263	-3.53251	-0.95579
1.693567	1.034752	-2.08325	1.770413	2.200128	2.508823	1.377544	4.473596	0.358971	3.405616	3.057224	4.280987	1.890441	2.657037	1.079451	-1.20287	2.53645	3.079905	2.617057
1.777298	0.282254	1.657842	-1.38849	-1.00277	-0.8442	0.522698	-1.84788	-0.71445	-1.11121	2.768267	-1.57824	1.356958	0.130783	-1.04225	-0.32622	-0.34745	1.614392	-1.06308
1.91953	-1.54539	-0.0885	-1.12049	-0.62244	-0.23212	-1.47378	-0.4285	-0.86861	-0.29099	-0.50554	-0.39982	0.256855	-0.10142	1.044914	-0.12127	0.249889	0.69557	0.144045
-0.85121	2.446204	0.394227	2.39726	0.771144	1.300152	1.515346	-0.2126	2.000469	0.206955	0.553886	0.358007	0.84424	1.072533	1.469354	-1.87015	1.441583	0.695031	-2.53877
0.510376	0.917563	-1.05038	-0.75016	-0.82765	-2.37522	-1.62439	-2.1203	0.443335	0.031344	-0.81746	-1.12226	-1.06719	-1.39807	-1.83042	-0.56164	-1.9786	-2.80368	0.152594
1.356157	-0.52565	1.492374	1.03567	-2.0371	0.021098	3.791017	-2.98738	0.648745	0.467771	3.123313	1.267366	2.799394	1.786674	-0.27794	2.999297	-1.00188	-2.20757	3.679278
0.891375	1.776335	0.774344	-0.30234	1.362869	-1.05868	1.014487	1.266877	0.044281	-0.83236	-2.31977	-2.74361	-0.94391	-2.15532	-0.41239	0.974577	0.7451	2.718647	-2.79433
-2.06458	0.207076	-0.55677	0.16167	-0.8366	0.080068	0.431836	-0.76379	-0.29631	0.323159	-0.63059	-1.4809	-1.02357	0.110258	-0.8612	1.035766	0.246379	-0.85905	0.324623
3.492468	1.93553	-0.06006	1.234599	0.715796	0.586051	0.933333	0.222786	0.413477	4.732999	3.411583	3.477247	1.509561	2.581677	1.877808	-1.0017	0.521347	-0.18666	2.174863
-0.77747	0.345544	-0.41772	0.599897	0.454015	-0.88738	-2.63673	0.216381	-0.82885	-1.16065	0.169303	-0.5601	-0.68569	-1.57154	-1.04866	-3.18597	0.500569	-0.52964	-1.93651
2.796038	3.429411	1.881354	2.393213	2.507135	2.330479	1.375162	1.600398	-1.53114	3.052407	2.995239	1.404568	2.203688	0.048377	-1.33787	1.818517	1.485098	1.22053	-0.41197
3.909391	1.334426	1.964624	0.05428	0.498122	2.054209	0.83498	2.726397	2.217052	2.16975	1.747984	2.353073	0.759081	2.699377	3.239977	-0.77657	3.519927	2.824895	0.509952
-2.1816	0.06662	-4.19807	1.409521	1.082021	1.303028	-0.99642	0.640894	-0.17822	-2.46819	-2.50654	-2.10528	-0.24451	-1.25917	-1.95264	-2.42019	0.767354	1.470197	-1.9382
-1.6264	0.645174	-3.25293	-0.95738	0.834321	-1.07844	-2.29225	1.944952	-3.1606	-0.40471	-2.19595	-2.01431	-2.81848	-1.18355	-1.49026	-2.06926	0.107023	2.657952	-2.68703
-2.0032	-1.08407	-3.39414	-2.03322	-1.01285	-2.2737	-0.46082	-1.28645	-1.83857	1.806055	0.322177	-0.15525	-0.93431	-2.14122	-2.23658	-3.53829	-2.84042	-2.24453	-1.18589

* Odd sample was excluded for the normal distribution of the data.

Appendix A.19 Differences of 20 participants' average Theta power between Weak and Intense patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
1.885938	0.203922	1.084781	-1.05127	0.433018	-0.27603	0.512112	-1.23212	1.300856	1.307664	1.608265	0.574074	1.370105	1.365086	1.343929	-0.21498	-1.32132	-2.5329	-1.55733
0.261241	0.310876	-0.65093	-0.2371	0.707268	-1.46057	1.922404	1.783541	2.214835	1.371785	-1.06553	-0.01688	0.496476	-1.26163	1.221621	1.17188	0.848151	1.926215	*
-0.58168	-1.13126	-0.14875	0.914829	0.290486	1.181507	-0.04423	-0.04063	0.008307	-0.03502	-0.28702	0.631682	0.301758	-0.10411	0.13201	0.490108	1.299958	0.848058	-3.22748
-1.66895	-3.35369	-0.67468	-2.19807	-0.96514	-1.14189	0.067279	-0.02214	2.60251	-1.22443	-0.40252	-1.67445	-0.58368	-1.64924	1.311	-0.8101	0.21759	0.505221	0.651297
-1.79912	-0.15865	-0.72992	0.850112	-0.28493	-0.28947	-1.21133	0.2048	-0.90355	-0.86149	-0.82637	-1.30163	-1.37945	-0.64335	-1.98307	-0.30802	-0.99682	-0.06428	-1.95468
2.929817	0.67061	0.927477	1.32801	-0.03841	1.493071	1.813926	-0.57551	-1.08307	3.618251	1.593122	3.707272	1.240404	1.422336	2.060713	1.157339	-0.17006	-0.93638	-1.06564
-0.62646	-0.88067	-1.06146	0.357357	-1.63334	-0.36893	-2.08001	-2.1324	-1.52306	0.039232	0.261768	0.333292	-1.19969	-0.592	-1.37815	-0.84917	-0.48206	0.67262	-2.30743
-1.33109	0.178951	-1.35447	-0.85384	-0.47117	0.014576	0.568034	0.027095	1.632066	0.831017	-0.13949	-0.19014	1.248004	0.607847	-0.04871	-0.02929	-0.75675	1.788125	0.937187
-2.17855	-0.26663	*	-1.51345	-0.8085	-0.77263	-0.03828	-0.02367	-1.37176	0.010371	-2.33278	-2.73202	-0.96937	-1.55011	-0.30769	-2.22175	-0.90909	0.102662	-2.5321
-0.02258	-2.01944	-0.44965	-1.72346	-1.994	-0.62693	0.075604	0.345296	-0.44316	-0.87058	0.801568	-0.838	0.022282	-1.28813	0.074851	-1.24547	0.441248	2.562762	-1.87778
0.934462	-1.61916	-0.84219	-2.0244	-1.18266	-2.00313	-0.34102	-0.89573	0.955093	0.300312	-0.10058	0.108693	-0.65721	-1.42966	-1.23358	-0.05587	-1.61294	-0.26873	0.067893
-3.368	-1.90589	0.105837	-0.75902	-1.24495	0.392025	-0.67876	-1.40497	-0.83483	-3.53042	-0.90562	-0.75553	-0.85738	0.302087	0.858045	-1.56545	0.250094	0.436141	-1.94401
0.354496	-2.98929	1.329357	-2.9951	-1.11332	-2.26182	-0.75354	-0.86517	-2.77942	-1.75614	-1.1969	-2.09867	-1.70993	-1.0038	-1.41392	-0.11967	-1.08404	-1.43433	-2.61471
-0.02521	-0.99421	0.335867	0.476793	-0.00033	1.01059	1.554946	-0.77474	-2.92451	-0.01208	0.555134	1.086255	2.171822	1.721949	1.399049	*	-0.39002	-2.40653	1.792829
-1.77303	-2.41917	-1.45162	-1.62202	-3.59077	-1.51945	-1.3855	-2.08506	-1.88789	-1.40634	-0.20708	-1.00725	-1.48329	-0.72041	-2.78344	-0.17753	-3.32285	-2.46995	-1.93244
3.616858	0.701527	3.066067	1.285967	-1.67719	1.832464	2.976152	-2.00325	2.413018	2.666964	*	2.264099	*	0.637005	2.160934	*	-0.67571	-1.27675	-0.06328
0.026946	-0.18704	-0.965	-0.35532	-0.04727	0.519063	-0.54652	1.106272	0.068137	-0.0349	0.128372	-0.07672	-0.51928	0.256877	-0.3889	-1.24596	1.917722	2.796859	0.264995
0.035674	1.20782	0.631553	0.212121	0.0852	0.145673	1.248891	-0.51946	2.096294	1.049367	0.504454	1.266733	-0.24862	1.768649	-0.58081	-0.78437	-0.88644	0.427624	0.222929
0.212355	-1.89804	-0.09693	-4.05141	-1.56805	-2.83259	-0.82982	-0.36153	-0.80921	-2.11269	-0.89253	-2.6818	-0.56177	-1.66742	-0.95092	-0.31744	-3.01869	-0.87138	0.469413
-2.1894	-0.78537	-2.45842	-1.27316	-2.13545	-1.95626	-1.45342	-2.2957	1.231682	-1.05752	-1.02478	0.284621	-1.48309	-1.68025	-0.96435	-1.08608	-2.03437	-1.09931	-1.06731

* Odd sample was excluded for the normal distribution of the data.

Appendix A.20 Differences of 20 participants' average Alpha power between Weak and Intense patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
0.830671	1.964083	2.051798	2.047154	1.010813	1.075809	1.63887	0.673306	0.883799	0.741229	0.249284	1.712521	0.675756	0.881567	1.681419	*	1.021646	-0.56699	2.091697
0.878307	1.755462	1.563148	0.800112	0.898916	0.541107	1.935758	0.879467	2.154122	2.037672	1.540577	1.538767	1.338886	1.281364	1.862368	1.593887	1.228906	0.927663	2.642894
1.228685	1.544524	2.257516	2.215392	-0.0988	1.673204	1.992872	-0.77827	-0.72102	1.459382	2.137975	0.838505	2.242237	1.18073	1.411024	*	0.819625	1.259426	0.038629
-1.26069	0.564076	-2.25137	-0.72809	-0.28019	-0.69627	-0.4526	-1.25866	-2.81478	-0.4362	-1.99222	-2.03655	-1.06452	-1.03581	-0.52503	-0.5731	0.213389	-0.54966	-0.99544
-0.54227	-1.63533	-0.28487	-1.6571	-1.75191	-0.65505	-1.80263	-1.65557	-2.81076	-2.62757	-0.34234	-0.32924	-0.95419	-0.70575	-2.15914	-0.13161	-1.51786	-1.25778	-1.45878
-0.27784	1.565927	-0.9769	2.885081	0.582854	3.120824	-0.2481	-0.30873	-1.28616	1.536663	1.2448	2.224602	0.259197	3.224174	1.732006	-1.20101	0.277065	-2.1422	-0.49581
-0.99112	0.711731	-2.17587	-1.39342	-2.66718	-1.09681	-0.32231	0.911485	-0.8235	0.378133	0.696025	0.901455	1.129489	-0.0006	-2.30963	-1.08197	-0.38103	0.522614	-1.61154
1.192964	3.519868	0.965118	2.840365	2.745258	2.54247	-0.30307	*	1.083865	2.368081	0.896431	0.766223	1.345569	0.376039	0.304	1.191993	1.741478	0.942931	1.652444
0.216863	-1.16406	-0.44859	0.027388	-0.40357	-0.08957	0.593349	-0.93363	-1.64932	0.290958	1.44667	0.798255	1.000608	0.411676	-1.21793	-0.3171	-1.07139	-1.43847	-0.97469
-0.31449	-1.76063	-1.0493	-0.77383	-1.04913	-0.83186	-1.75021	0.699863	-1.02868	-0.30913	-0.97223	-0.54783	-2.33104	-1.94239	-0.64543	-0.60844	0.515594	1.91417	-1.82905
-1.24591	-2.2638	-1.84436	-2.53013	-0.89019	-0.98151	-1.22729	-0.55661	0.381279	-0.37734	-2.43192	-1.94144	-2.2448	-2.05264	-1.45833	-1.87076	-0.48366	-0.31124	-0.6478
-0.13629	-1.30384	-0.53359	-2.16898	-2.37662	-2.04103	1.444767	-1.3121	0.876551	-1.9672	0.082701	-0.45914	-0.55696	-0.60253	-0.04815	-0.6653	-1.27485	-0.39332	-0.97354
-0.5733	-0.39454	0.083455	0.538031	-0.89576	-0.46875	-1.35477	-1.21202	-1.11891	-1.17822	-0.13975	1.284948	-1.36041	-1.20835	-1.26988	-0.78018	-0.07452	-1.45744	1.260148
-2.2838	-0.79953	-0.3678	-0.83077	0.142881	-0.77889	-3.30335	0.005804	-2.25848	-0.86303	-1.73109	-1.67258	-2.12486	-1.94007	-2.20469	-0.08068	-0.80349	-2.06988	-0.81683
0.186139	-2.04551	-0.24853	-0.9424	-0.7755	0.755386	0.157639	-0.80446	-1.25908	-1.81152	-0.93681	0.017611	-0.1883	-0.08255	-3.27173	-1.12669	-3.03217	-0.76862	-1.26592
1.008049	0.337707	1.311168	0.933415	2.229065	-0.36626	0.434888	*	1.703001	-1.91483	1.00889	-0.61862	0.962003	-0.34005	0.29784	1.225366	2.192207	2.623787	1.074962
0.068521	1.08199	-0.87921	-0.12938	1.241516	0.529244	-0.28361	-0.74046	2.146798	0.732059	-0.94937	-0.51273	-1.37662	-0.28007	2.499535	-0.8567	0.786367	-0.81611	-0.18186
0.876487	0.367029	0.20605	0.93725	1.833141	1.026556	0.454273	0.619385	1.349903	-0.99156	0.85023	1.526104	0.962054	1.907778	2.13314	-0.43257	-0.33239	0.112273	0.487944
-1.72038	0.416499	0.156808	1.065516	1.288711	0.32856	0.104661	*	-0.25013	0.158582	-0.02175	-0.13362	-0.05613	-0.72686	-0.94017	-0.65121	0.111214	1.852047	-0.33324
-0.40959	-2.50211	-1.30365	-2.91474	-3.35842	-2.46812	-1.15668	-1.21831	-0.2577	-1.27208	-0.89069	-1.22427	-1.24963	-1.36168	1.076246	0.934451	-1.18808	-0.61153	-1.2423

* Odd sample was excluded for the normal distribution of the data.

Appendix B.21 Differences of 20 participants' average Beta power between Weak and Intense patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
0.662806	1.0937	0.415338	-0.09552	-0.21522	-0.82863	0.467706	-0.98131	0.39028	-0.09533	1.49162	0.177955	1.062569	0.049531	0.102929	0.220152	-0.67834	0.014155	-0.39289
2.526512	3.903113	2.85108	*	*	2.53629	*	2.496613	4.663897	4.640411	3.174456	*	*	2.399422	*	*	2.701482	2.733722	*
0.970224	0.351698	0.6817	0.259339	-0.46083	1.020553	0.94779	-0.95282	0.269967	-0.10513	0.491443	0.081165	0.47813	0.545144	1.403325	1.400249	0.442982	0.787252	1.006096
0.214879	0.033237	0.7723	0.206124	0.753816	0.219609	0.06371	-0.24245	-0.12301	0.66827	0.326441	0.340055	0.343952	0.409258	0.642241	0.340166	0.043573	-0.55619	-0.19626
-3.55861	-0.80713	-1.55532	*	-2.01424	-2.11319	-1.6346	-1.18471	-1.54109	0.212518	-3.10568	-2.20609	-2.48384	-2.20309	-2.07805	-1.35535	-1.64269	-1.79969	-1.87209
1.740081	-0.01996	0.783756	-0.05315	-1.12685	-0.69425	0.53223	-0.92845	0.758007	1.515776	1.088098	1.320559	-0.1618	-0.8582	-0.23192	0.857408	0.229085	0.226249	-0.14737
0.653561	-0.24317	0.901509	-0.22975	-0.91969	-0.11274	0.069836	-1.62985	-0.19906	-0.0582	0.218765	0.767803	0.988453	0.954941	0.913679	-0.07202	-0.43117	-1.44189	0.455497
0.49264	0.265854	-0.10994	0.718308	0.370309	1.058712	-0.46889	0.703974	0.025353	0.312342	-0.10442	0.576938	-0.24131	0.393524	-0.20557	0.393717	0.890709	0.183629	-0.17593
-1.40304	-0.5485	-0.17636	-0.69079	0.252612	0.359296	-0.91515	0.821682	0.708473	-1.05993	-0.17373	-0.38515	-0.38964	-0.05563	-0.54893	-0.74199	-0.08821	0.509314	0.017374
0.091471	0.015725	-0.49497	-0.56994	-0.17804	-0.49473	-0.33626	-0.48591	1.928647	-0.16783	-0.49623	-0.24113	-0.16681	-0.42766	-0.08896	-0.61545	-0.27471	-0.85782	0.514308
-0.83496	-1.05567	-1.66321	-0.89498	-0.98983	-0.0226	-0.60073	-0.73076	0.555464	-0.17571	-2.29581	-1.26405	-1.61178	-1.00113	-0.87938	-2.00709	0.084256	0.402978	-1.34555
-0.75839	-0.11561	-0.97165	0.716697	0.943607	0.639488	-1.34531	1.971794	-0.68547	-0.83091	-0.89997	0.426439	-0.96545	0.384212	-0.42811	-0.44159	1.428235	1.655804	-1.94494
-0.38735	0.213446	0.431774	0.107062	0.304514	-1.09603	0.385464	-0.55989	0.122029	-0.43757	-0.43854	-0.83561	-0.48551	-1.31302	-0.40996	-0.68178	-0.47856	-0.1346	0.087452
-1.01971	-0.72959	0.2906	0.184352	0.193359	0.476259	-0.1119	-0.37952	-0.97173	-0.03564	-1.08681	-0.38214	-0.16033	0.140262	-0.00453	-0.0636	-0.29912	-2.04999	1.133826
-1.46311	-1.4469	-1.80495	*	-2.10833	-2.94139	-3.20297	-2.80281	-1.42702	-1.18335	-2.36639	-2.43899	-2.50398	-2.76226	*	-2.56467	*	-0.83159	-1.78001
0.312966	-0.09046	0.945873	0.036471	-0.06218	0.724126	1.951712	-0.09732	1.309475	0.465682	1.194993	1.028936	1.375697	1.489119	0.932563	1.425891	0.247594	0.226263	1.653729
1.265404	0.019208	0.531905	0.158666	0.033454	0.920331	0.444344	0.887081	1.192461	0.771158	1.113439	0.231897	0.534615	0.70734	1.063496	0.335475	1.177208	0.711518	0.666485
-0.35243	-1.68516	-0.87078	-1.59636	-0.61469	-0.92076	-0.44586	0.127428	-0.9242	-1.64541	-0.86079	-1.40981	-0.53837	-0.66847	-0.29395	-0.89017	-0.64309	-0.11692	-0.64898
-1.0498	0.20098	-0.50327	-0.2691	0.452897	0.055185	-1.03252	0.952902	-0.40147	-0.56513	-0.02903	0.137974	-0.3408	-0.3672	-1.11426	-0.06213	-0.01238	-0.0183	-0.18081
-0.47742	0.983452	-0.87788	0.268436	0.240994	-0.36326	-0.32972	1.118377	-0.68443	0.936898	-0.33267	-0.02225	-0.31503	0.7485	2.131329	-0.98099	1.08652	1.342203	-0.74125

* Odd sample was excluded for the normal distribution of the data.

Appendix A.22 Differences of 20 participants’ average Gamma power between Weak and Intense patterns.

F8	T6	Fp2	P4	O2	Pz	F3	O1	T3	T4	F4	C4	Fz	Cz	C3	Fp1	P3	T5	F7
0.182638	-0.17051	0.033988	-0.26562	-0.6182	-0.62668	0.439325	-1.32257	0.388329	0.210333	0.285302	-0.03533	0.513352	0.075932	-0.19089	0.233024	-0.77501	-1.26945	0.462744
*	6.40271	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
-0.28077	-0.20099	0.321088	-0.75207	-0.32982	-1.08166	0.478347	-0.98907	-0.2002	-0.38318	0.441655	-0.45205	-0.09902	-0.14454	0.023987	-0.47357	-0.67158	-0.93736	-0.87949
0.76242	-0.24538	0.697934	-0.03218	0.042392	0.408686	0.119032	-0.296	0.180249	0.213801	0.570919	-0.02361	0.512857	0.587179	0.426535	0.159256	0.070113	-0.36578	-0.36428
-4.32851	-2.13884	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1.747028	1.069815	0.803336	0.786507	0.162932	1.311427	1.398171	0.176386	0.749085	2.248345	1.337032	1.436139	1.501309	1.12506	0.735423	1.114581	0.78424	-0.19494	0.655447
0.195936	0.19358	0.311524	-0.21563	0.526221	-0.13792	0.033296	0.227653	-0.42826	-0.21213	0.501997	-0.24711	0.281544	-0.06864	0.774945	-0.22629	-0.1237	-0.49209	-0.18861
-0.66282	-0.94871	-0.62529	-0.48829	-1.18307	-1.10666	-1.5416	-1.09858	-0.99035	0.167826	-1.10784	-0.12594	-1.43154	-1.0608	-1.2041	-0.8616	-1.00502	-0.83768	-0.71018
-0.10924	1.381375	-0.7292	1.211034	0.331672	1.112397	0.55968	0.897011	1.136645	-0.47522	0.912353	0.007817	0.699825	0.516988	-0.13047	0.119427	0.759463	1.291437	0.499
0.402193	-0.52472	0.245994	-0.90328	-0.30177	-0.66435	0.217431	-0.53304	1.175678	-1.72518	-0.15484	-1.20056	-0.73192	-0.92622	0.67919	0.290506	-0.1164	0.278497	0.285298
0.138902	0.13099	-0.09485	0.284147	0.948122	0.343184	-0.33813	0.836399	0.456037	1.064503	-0.58214	-0.15877	-0.51541	-0.35938	-0.46097	0.202796	0.397896	-0.18109	0.341235
-0.75103	0.547297	-1.44823	0.905691	1.317419	0.71808	-1.72844	0.685222	0.887729	-0.71049	-0.41403	0.489965	-1.09892	-0.0794	-0.6549	-1.57625	0.921792	1.059789	*
-0.03292	-0.2576	-0.24614	-0.18122	-0.02447	-0.36353	0.526302	-0.13461	-0.89172	0.062244	0.74552	-0.00729	0.244	0.063596	-0.0383	0.196759	-0.55	-0.43967	0.261735
-0.67137	-0.71024	0.281472	-0.66948	-0.42301	-1.13982	-0.79588	-1.32182	-0.50015	-0.21307	-0.94556	-0.9023	-0.86642	-1.01211	-0.95971	-1.13635	-1.40055	-1.68285	0.551797
-1.70892	-1.55155	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
-0.95959	-0.22583	-0.75076	-0.12898	0.282995	-0.20393	0.282216	0.726411	-0.11713	-0.09018	0.09304	0.179988	0.432805	0.256332	-0.07884	-0.70376	0.244133	0.223411	0.599163
0.643848	0.74242	-0.35406	-0.13264	-0.23626	-0.02473	-1.22933	-0.03218	-0.11836	0.90154	-0.31251	0.328831	-1.14366	-0.41831	0.261284	-0.08081	0.111732	0.645032	-0.54831
0.619743	-0.18639	0.290367	0.233132	-0.75182	0.816514	0.83264	-0.17046	0.909454	-0.809	0.427341	0.621553	0.841029	1.329825	1.451613	-1.17337	0.883757	-0.11557	0.283282
-0.5959	1.519968	0.431906	1.00587	1.015604	1.159931	0.140822	0.329581	-0.09788	-0.04217	1.224844	1.12814	0.459175	0.76191	-0.11076	0.234708	1.020021	0.969149	0.405472
0.677099	-0.3079	0.419469	0.573077	0.622569	0.549649	0.411455	0.900487	-1.07424	-0.32436	0.876111	0.873281	0.369203	0.584785	2.028596	1.147876	0.008429	-0.61731	-0.50047

* Odd sample was excluded for the normal distribution of the data.

Appendix A.23 20 participants' Frontal Alpha Asymmetry index for Weak patterns.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
1.30238	1.01211	0.290268
2.17509	2.54903	-0.373937
2.72478	2.47162	0.253166
0.53642	0.01102	0.525406
1.85899	1.42666	0.432336
0.70211	-0.27395	0.976052
0.4332	0.06755	0.365656
3.2489	2.47222	0.776676
1.09573	0.48847	0.607254
1.01817	1.08143	-0.063264
0.67528	0.75395	-0.078674
0.91448	0.82794	0.086543
1.27195	2.22829	-0.956336
0.93417	1.57883	-0.644658
1.15087	0.9285	0.222372
2.10196	1.38647	0.715498
0.68435	0.28232	0.402022
3.00686	2.74076	0.266109
2.41557	1.41889	0.996677
-0.00302	0.62829	-0.631312

Appendix A.24 20 participants' Frontal Alpha Asymmetry index for Intense patterns.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
0.25846	-1.01616	1.27462
0.84775	0.49151	0.35623
0.85006	1.0828	-0.23274
2.37118	0.68473	1.68645
2.24882	2.55766	-0.30884
0.70542	0.37436	0.33106
1.25686	1.07282	0.18404
2.23073	1.6251	0.60563
0.69074	0.72128	-0.03054
1.79684	2.47733	-0.68049
2.51601	2.00256	0.51344
1.1102	0.89263	0.21758
1.48181	2.51989	-1.03807
2.39506	2.97911	-0.58405
1.48394	1.67349	-0.18955
0.99259	0.47473	0.51787
1.27103	0.72304	0.54799
2.36261	2.57087	-0.20826
2.94401	1.71216	1.23185
0.86496	1.11647	-0.25151

Appendix A.25 20 participants' average heart rate changes (bpm) on each second window when responding to Weak patterns.

Time Window / Participants	1s	2s	3s	4s	5s	6s	7s	8s	9s	10s
1	3.22907	4.28258	2.66351	0.24347	-1.7098	-2.7697	-3.98576	-2.98921	-2.85186	-2.7714
2	-1.06065	-1.50788	-1.99576	-2.26599	-2.0881	-2.26145	-2.36761	-2.66388	-3.4302	-3.4949
3	0.04863	0.42667	-2.37066	-3.36671	-1.4196	2.29064	-4.41958	-2.08315	0.46335	-1.9477
4	1.16929	0.54243	0.26798	-0.40145	-0.852	-1.2263	-0.63327	-0.38093	0.59439	0.5261
5	0.89714	0.99011	-0.51537	-1.70909	-1.6201	-1.93709	-2.6644	-2.93008	-3.00695	-3.2231
6	-2.31571	-4.42634	-2.17096	-1.8857	-2.0945	-0.22967	-1.73881	-2.04442	-1.65959	-3.4779
7	-4.40057	-5.86704	-6.62344	-9.79007	-10.2949	-6.86122	-5.49096	-3.21245	-2.63446	-3.4857
8	-0.01699	-1.1143	-1.60043	-2.81073	-4.3172	-4.81037	-3.31	-1.78902	-1.21811	-2.0079
9	-0.73337	-1.73663	-2.7115	-3.78128	-4.3214	-4.86548	-4.93262	-4.22503	-4.36578	-4.853
10	-2.50213	-3.5321	-3.82858	-3.42189	-2.8324	-2.29593	-1.87204	-1.6659	-1.24644	-0.9643
11	-0.01719	-0.13064	-0.64966	-1.3991	-1.7321	-2.39352	-2.43146	-2.85951	-2.78483	-2.1714
12	0.72698	2.51128	3.17915	2.92175	1.2034	3.43623	-0.94957	0.52512	1.17917	1.6469
13	-3.24143	-3.14935	-3.9958	-6.09728	-6.4442	-5.09222	-6.81378	-6.63886	-6.67415	-8.1222
14	-1.94691	-1.17216	1.85661	1.01898	-1.2363	-1.06691	-1.68833	-3.48957	-3.08906	-2.1118
15	-2.18743	-0.93123	-4.24973	-0.01992	-7.6203	-9.89658	-9.1761	*	*	-12.5488
16	-3.49135	-4.15107	-4.82657	-5.33664	-6.817	-7.32425	-8.16078	-8.209	-8.69232	-9.1499
17	-1.26136	-3.3369	-5.611	-7.30336	-4.8623	-1.77755	-1.37041	-1.55253	-2.66312	-3.6753
18	2.43898	3.14707	2.57311	3.7235	-0.2183	1.51291	2.82841	0.49162	-0.82938	4.5877
19	-6.15568	-6.05193	-7.90908	-6.74349	-8.1769	-8.76818	-8.06293	*	*	-9.8594
20	-0.07752	-0.18962	-0.24029	-0.51193	-0.8316	-1.28946	-0.55435	0.54556	0.0489	-1.3685

* Odd sample was excluded for the normal distribution of the data.

Appendix A.26 20 participants' average heart rate changes (bpm) on each second window when responding to Intense patterns.

Time Window / Participants	1s	2s	3s	4s	5s	6s	7s	8s	9s	10s
1	1.94952	3.39942	2.99887	2.36153	2.0405	1.03001	0.80568	1.93606	1.65742	0.7201
2	-0.5754	-0.0989	-0.2053	-0.3086	-1.09051	-2.3213	-3.1228	-3.532	-3.6067	-3.0107
3	-1.1653	0.76485	1.94462	1.03708	-1.22702	-1.0603	0.7021	2.19072	1.21777	-0.0109
4	0.14942	-0.6248	-0.3555	-1.1568	-0.43686	-0.0536	0.51728	1.38986	1.05317	2.05878
5	-1.2963	-2.3169	-2.9793	-3.1965	-2.99405	-3.6499	-4.8242	-5.3646	-4.5623	-4.3813
6	0.03181	-3.8376	-1.3132	-1.3157	-2.74415	0.22039	-0.2482	-0.8069	0.93014	-0.4234
7	1.29634	-5.188	-6.7121	*	-7.55335	-7.466	*	*	*	-9.5436
8	-1.9236	-1.9525	-1.5641	-2.4029	-1.86696	-2.2182	-0.7327	-0.6612	-0.7467	-0.6396
9	-1.0512	-1.7051	-2.0264	-2.4353	-2.66657	-3.1153	-3.6392	-4.0992	-3.7359	-2.4008
10	-1.9301	-2.5146	-2.5963	-1.6876	-0.64402	0.14694	0.22353	0.71683	1.32699	1.59219
11	-2.5738	-1.9625	-1.3636	-1.3225	-2.63765	-4.1458	-3.7408	-3.2643	-2.9862	-2.4795
12	-4.1939	-3.9267	-1.0757	-1.3152	-2.61522	-3.2442	-2.8718	-1.5239	-1.782	-2.6412
13	-3.4273	-1.1616	-0.8552	-1.5593	-1.83209	-0.4139	-0.6994	-1.5709	-2.9733	-4.2258
14	-1.3793	-1.1585	1.13669	0.64823	-0.49855	0.57502	1.58375	-0.1227	-0.0581	1.84653
15	-2.282	3.26073	6.70885	1.07264	0.91695	6.06612	1.55396	0.81356	2.60177	1.87385
16	-1.7125	-2.1314	0.68032	0.76958	-2.47742	-5.1636	-3.806	-3.5746	-5.017	-4.6255
17	-3.1806	-3.2933	-2.3104	-4.0159	-6.64703	-7.6724	-5.7357	-3.9874	-4.7371	-5.7168
18	1.3412	5.17964	2.60099	1.98653	1.4321	-1.051	-3.8028	0.62504	0.76987	0.80975
19	-6.6067	-8.4052	*	*	*	-9.0837	-8.7984	-8.89	*	*
20	1.92448	0.4468	-0.4003	-0.9762	-0.27236	0.04789	-1.2809	-1.6963	-0.8904	-0.474

* Odd sample was excluded for the normal distribution of the data.

Appendix A.27 20 participants' differences of heart rate changes (bpm) when responding to Weak and Intense patterns on each second window.

Time Window / Participants	1s	2s	3s	4s	5s	6s	7s	8s	9s	10s
1	1.27955	0.88316	-0.33536	-2.11806	-3.75033	-3.79971	-4.7914	-4.92527	-4.50928	-3.49145
2	-0.48524	-1.40896	-1.7905	-1.95735	-0.99757	0.05987	0.7551	0.86811	0.17648	-0.48419
3	1.2139	-0.33818	-4.31528	-4.40379	-0.19256	3.35098	-5.1217	-4.27387	-0.75442	-1.93681
4	1.01987	1.16718	0.62344	0.75538	-0.41511	-1.17273	-1.1506	-1.77079	-0.45877	-1.53272
5	2.19343	3.30697	2.46397	1.48737	1.37395	1.7128	2.1598	2.43455	1.55531	1.15819
6	-2.34752	-0.58872	-0.85778	-0.56999	0.64964	-0.45006	-1.4906	-1.23757	-2.58973	-3.05455
7	-5.69691	-0.67907	0.08865	-1.32433	-2.74151	0.60482	5.76	8.01629	*	6.05789
8	1.90659	0.83825	-0.03637	-0.40784	-2.45021	-2.59218	-2.5773	-1.1278	-0.47139	-1.36829
9	0.31782	-0.03151	-0.68512	-1.34594	-1.65485	-1.75022	-1.2934	-0.12585	-0.62983	-2.45218
10	-0.57199	-1.01753	-1.23227	-1.73426	-2.18836	-2.44287	-2.0956	-2.38273	-2.57343	-2.55648
11	2.5566	1.83183	0.71395	-0.07661	0.90552	1.75229	1.3093	0.40479	0.20133	0.3081
12	4.92084	6.43797	4.25481	4.23695	3.81859	6.68048	1.9222	2.04905	2.9612	4.2881
13	0.18588	-1.98779	-3.14055	-4.53797	-4.61214	-4.6783	-6.1144	-5.06798	-3.70085	-3.89638
14	-0.5676	-0.01364	0.71992	0.37075	-0.73776	-1.64193	-3.2721	-3.36687	-3.03092	-3.95832
15	0.09458	-4.19197	*	-1.09256	-8.53728	*	-10.7301	*	*	*
16	0.4510125	2.35322125	2.24152	3.78805375	1.084995	0.315475	0.73548125	-0.79997125	0.35708875	0.8924775
17	-2.00199875	-0.63642375	0.1600175	0.46424375	-0.5592125	-1.3373525	0.726535	2.24189875	0.93934375	-0.89447375
18	1.01987125	1.16718375	0.6234425	0.755385	-0.4151125	-1.17272875	-1.15055	-1.77079125	-0.45877375	-1.5327225
19	2.19343	3.3069725	2.46396875	1.4873675	1.37395375	1.7128	2.15979875	2.43455375	1.55531375	1.15818625
20	-2.34751625	-0.58872125	-0.85778	-0.56998625	0.6496425	-0.4500575	-1.4906	-1.23756625	-2.58972625	-3.0545475

* Odd sample was excluded for the normal distribution of the data.

Appendix A.28 19 participants' average rating scores on the Valence scale to Weak and Intense patterns.

Participant	Average Rating Scores on Weak patterns	Average Rating Scores on Intense patterns	Differences between Weak and Intense patterns
1	1.000	0.500	0.500
2	-0.250	1.375	-1.625
3	0.875	0.500	0.375
4	0.750	1.500	-0.750
5	-0.375	0.875	-1.250
6	0.250	0.125	0.125
7	0.250	0.625	-0.375
8	-0.750	0.500	-1.250
9	1.250	1.000	0.250
10	1.375	0.875	0.500
11	0.375	-0.250	0.625
12	-0.375	0.125	-0.500
13	0.875	1.625	-0.750
14	0.500	-0.875	1.375
15	0.375	0.875	-0.500
16	-1.875	0.500	-2.375
17	0.500	2.625	-2.125
18	0.750	1.000	-0.250
19	1.000	0.125	0.875

Appendix A.29 19 participants' average rating scores on the Arousal scale to Weak and Intense patterns.

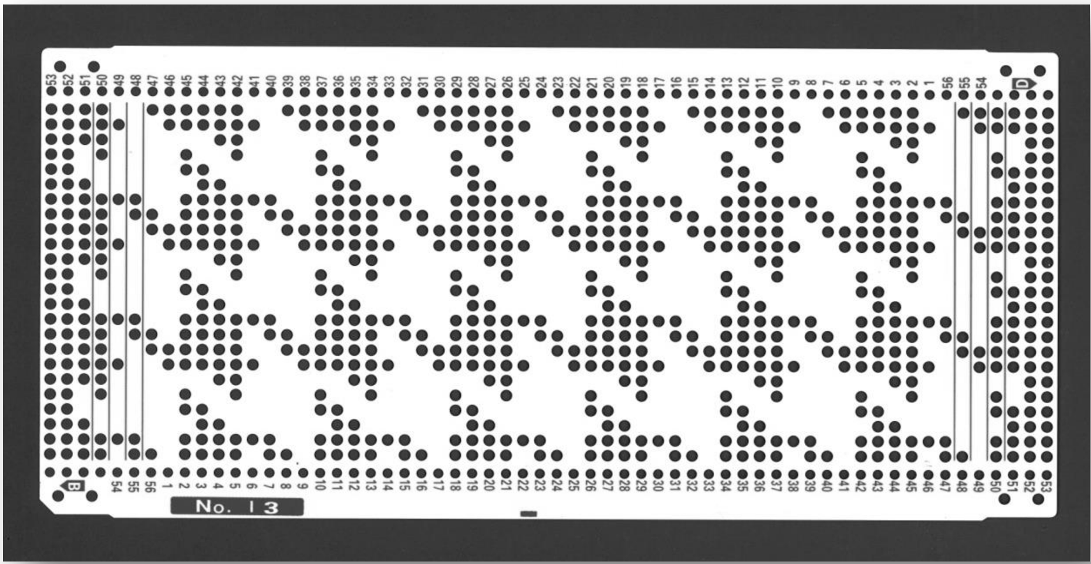
Participant	Average Rating Scores on Weak patterns	Average Rating Scores on Intense patterns	Differences between Weak and Intense patterns
1	1.125	0.625	0.500
2	0.125	-0.375	0.500
3	0.750	1.250	-0.500
4	-0.125	1.875	-2.000
5	-0.375	1.375	-1.750
6	-0.375	0.375	-0.750
7	-0.750	0.000	-0.750
8	-1.125	1.625	-2.750
9	-1.250	0.000	-1.250
10	1.125	0.625	0.500
11	0.375	0.875	-0.500
12	0.250	0.875	-0.625
13	-0.250	0.625	-0.875
14	0.750	3.125	-2.375
15	0.375	1.125	-0.750
16	-1.625	0.500	-2.125
17	-1.000	2.125	-3.125
18	0.750	1.000	-0.250
19	-0.875	1.500	-2.375

Appendix A.30 19 participants' average rating scores on the Likert scale to Weak and Intense patterns.

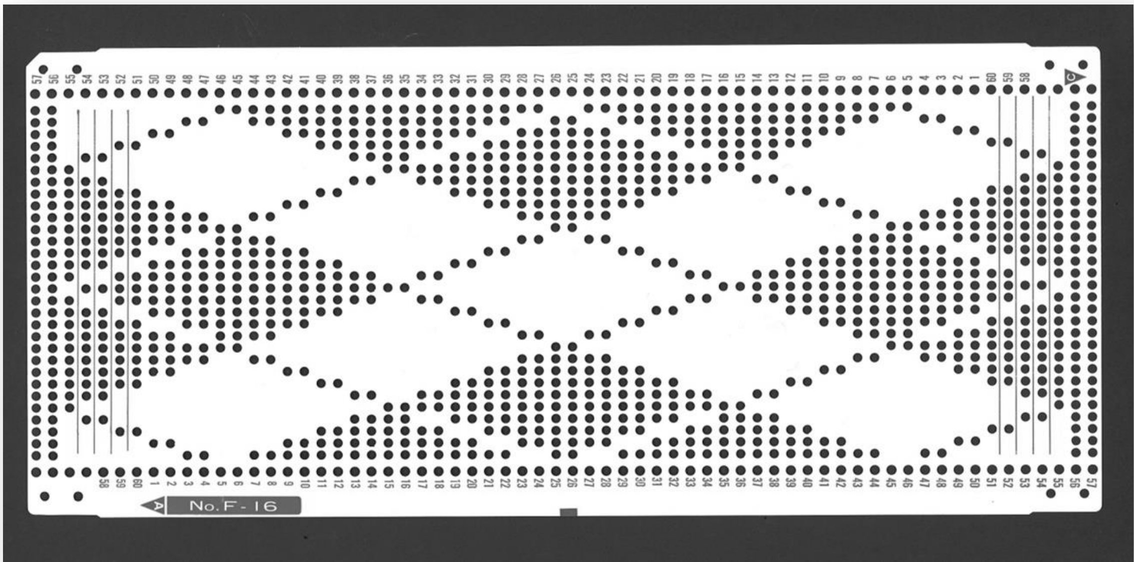
Participant	Average Rating Scores on Weak patterns	Average Rating Scores on Intense patterns	Differences between Weak and Intense patterns
1	1.000	0.625	0.375
2	0.500	1.625	-1.125
3	0.500	1.125	-0.625
4	1.125	2.125	-1.000
5	-0.375	0.875	-1.250
6	0.125	-0.375	0.500
7	0.250	0.625	-0.375
8	-0.250	0.250	-0.500
9	1.250	0.750	0.500
10	1.750	0.250	1.500
11	0.625	-0.125	0.750
12	-0.625	0.125	-0.750
13	1.125	1.500	-0.375
14	0.125	-1.250	1.375
15	0.250	0.750	-0.500
16	-1.875	1.125	-3.000
17	0.750	2.625	-1.875
18	0.750	1.000	-0.250
19	0.875	1.125	-0.250

APPENDIX B

Appendix B.1 Pre-designed Punch Card Used for the Production of Knitted Fabric Sample 1.



Appendix B.2 Pre-designed Punch Card Used for the Production of Knitted Fabric Sample 2.



Appendix B.3 The Design Information of the Knitted Fabric Sample 3.

The design of one repeating unit of the pattern

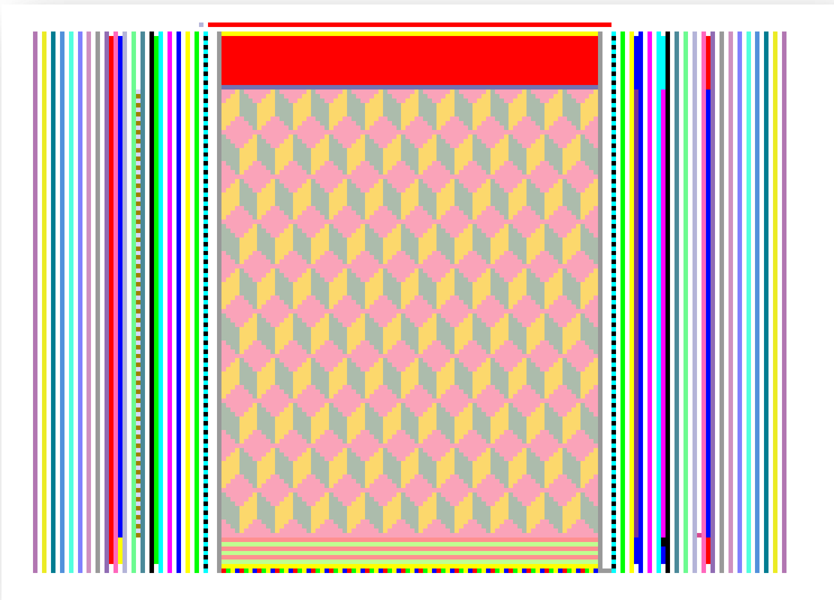
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X

X - 112 Tex cotton yarn in black colour

X - 100 Tex cotton yarn in grey colour

X - Coloured SMART yarn sample D

The design diagram on the software of Shima Seiki SES 122 S knitting machine



A three colour bird's eye jacquard structure

Appendix B.4 The Production Information of the Woven Fabric Sample 1.

Yarns: 2/19's cotton in black, 2/20's viscose in white,

Coloured SMART yarn C in dark grey

Reed Number: 15\4

Sett: 16 end per cm

Weaving Width: 16.5 cm

Warp Length: 4 ells

Shafts: 8 shafts, Shafts 1-4 require 14 heddles, Shafts 5-8 require 66 heddles

Warp Plan:

2/19's cotton in black	1	
2/20's viscose in white		1

Draft Shafts Pegplan

							x								x						1			x		x	x	x		x	x
						x								x							2					x				x	
					x								x								3			x	x	x		x	x	x	
				x								x									4			x				x			
			x								x								x		5						x	x		x	x
		x								x								x			6				x	x	x			x	
	x								x								x				7				x			x	x	x	
x								x								x					8			x	x		x	x			

1 2 3 4 5 6 7 8

12 8 40 8 12

288 (6 repeats)

Weft Plan

2/19's cotton in black	1	Repeat the columns 1-4 of the Pegplan for 30 times
2/20's viscose in white	1	
2/19's cotton in black	1	Repeat the column 5-8 of the Peglan for 6 times
Coloured composite yarn C in dark grey	1	

Appendix B.5 The Production Information of the Woven Fabric Sample 2.

Yarns: 2/19’s cotton in black, 2/19’s cotton in Grey, 2/20’s viscose in white,

Coloured SMART yarn C in dark grey

Reed Number: 15\4

Sett: 16 end per cm

Weaving Width: 16.5 cm

Warp Length: 4 ells

Shafts: 8 shafts, Shafts 1-4 require 14 heddles, Shafts 5-8 require 66 heddles

Warp Plan:

2/19’s cotton in black	1	
2/20’s viscose in white		1

Draft Shafts Pegplan

							x								x						1			x		x	x		x	x	x
						x								x							2					x					x
					x								x								3			x	x	x		x	x		x
				x								x									4			x					x		
			x								x								x		5						x	x		x	x
		x								x								x			6				x	x	x			x	
	x								x								x				7				x			x	x	x	
x								x								x					8			x	x		x	x			

1 2 3 4 5 6 7 8

12 8 40 8 12

288 (6 repeats)

Weft Plan

2/19’s cotton in black	1	Repeat the columns 1-4 of the Pegplan for 40 times
2/19’s cotton in Grey	1	
2/19’s cotton in Grey	1	Repeat the column 5-8 of the Peglan for 8 times
Coloured composite yarn C in dark grey	1	

Appendix B.6 The Information of Designs of the Knitted Fabric 1.

The design of one repeating unit of the pattern

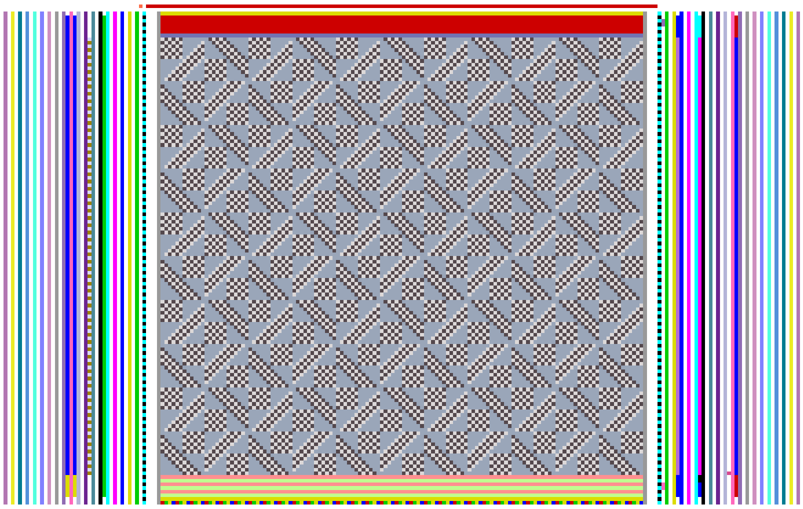
						o	x	o	x	o	x								x	o	x	o	x
X						x	o	x	o	x	o						o			x	o	x	o
O	x					o	x	o	x	o	x					o	x				x	o	x
X	o	x				x	o	x	o	x	o				o	x	o					x	o
O	x	o	x			o	x	o	x	o	x			o	x	o	x						x
X	o	x	o	x		x	o	x	o	x	o		o	x	o	x	o						
	x	o	x	o	x							o	x	o	x	o		o	x	o	x	o	x
		x	o	x	o						o	x	o	x	o			x	o	x	o	x	o
			x	o	x					o	x	o	x	o				o	x	o	x	o	x
				x	o				o	x	o	x	o					x	o	x	o	x	o
					x			o	x	o	x	o						o	x	o	x	o	x
							o	x	o	x	o							x	o	x	o	x	o
o	x	o	x	o								o	x	o	x	o	x						
x	o	x	o			x						x	o	x	o	x	o						o
o	x	o				o	x					o	x	o	x	o	x					o	x
x	o					x	o	x				x	o	x	o	x	o				o	x	o
o						o	x	o	x			o	x	o	x	o	x			o	x	o	x
						x	o	x	o	x		x	o	x	o	x	o		o	x	o	x	o
o	x	o	x	o	x		x	o	x	o	x							o	x	o	x	o	
x	o	x	o	x	o			x	o	x	o	x						x	o	x	o		
o	x	o	x	o	x				x	o	x	o	x					o	x	o			
x	o	x	o	x	o					x	o	x	o	x				x	o				
o	x	o	x	o	x						x	o	x	o	x			o					
x	o	x	o	x	o							x	o	x	o	x							

X - 100 Tex wool in dark grey

O - Coloured composited yarn sample D

Blank area - 112 Tex wool in white

The design diagram of the pattern on Shima Seiki SES 122 S knitting machine



A three colour bird's eye jacquard structure

Appendix B.7 The Information of Designs of the Knitted Fabric 2.

The design of the background of the pattern

x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x							x							x	x							x						
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

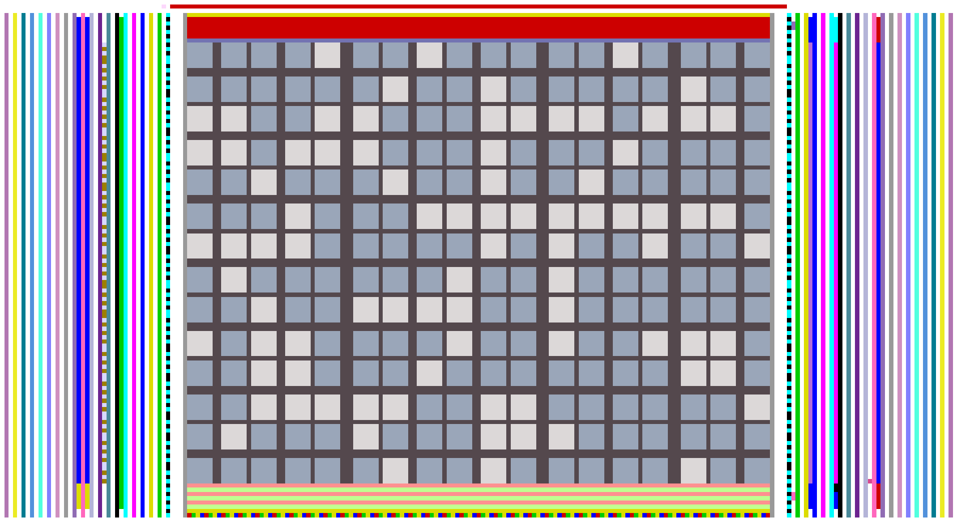
Repeat 2 times

X - 100 Tex wool in dark grey

Blank area - 112 Tex wool in white

O - Coloured composited yarn sample D partially filled in the blank area in the pattern

The design diagram of the pattern on Shima Seiki SES 122 S knitting machine



A three colour bird's eye jacquard structure

Appendix B.8 The Information of Designs of the Knitted Fabric 3.

The design of one repeating unit of the pattern

x	x	x	x	x	x	x	o	o	o	o	o	o	o	o	o							o	o	o	o	o	o	o	o	o	x	x	x	x	x	x
x	x	x	x	x	x	o	o	o	o	o	o	o	o	o									o	o	o	o	o	o	o	o	o	x	x	x	x	x
x	x	x	x	x	o	o	o	o	o	o	o	o	o											o	o	o	o	o	o	o	o	o	x	x	x	x
x	x	x	x	o	o	o	o	o	o	o	o	o													o	o	o	o	o	o	o	o	o	x	x	x
x	x	x	o	o	o	o	o	o	o	o	o															o	o	o	o	o	o	o	o	o	x	x
x	x	o	o	o	o	o	o	o	o	o																	o	o	o	o	o	o	o	o	o	x
x	o	o	o	o	o	o	o	o	o																			o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o																					o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o																							o	o	o	o	o	o	o
o	o	o	o	o	o	o																									o	o	o	o	o	o
o	o	o	o	o	o																											o	o	o	o	o
o	o	o	o	o																													o	o	o	o
o	o	o	o																															o	o	o
o	o	o																																	o	o
o	o																	x																		o
o																	x	x	x																	
																x	x	x	x	x																
															x	x	x	x	x	x	x															
																x	x	x	x	x																
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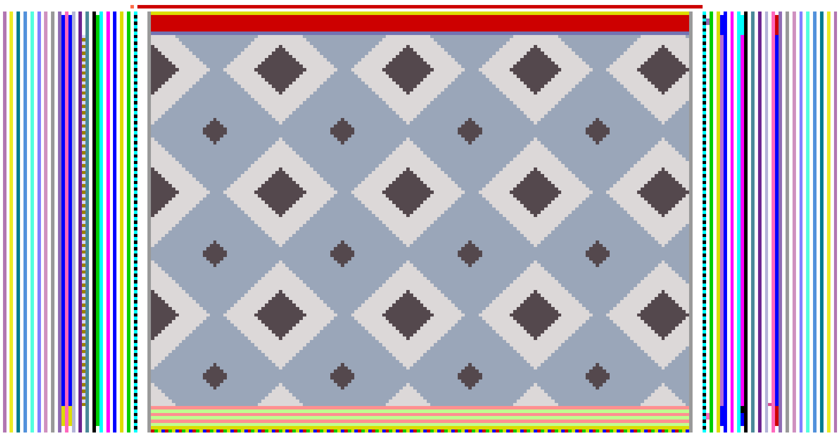
o	o	o	o	o	o	o	o																							o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o																					o	o	o	o	o	o	o	o
x	o	o	o	o	o	o	o	o	o																			o	o	o	o	o	o	o	o	o
x	x	o	o	o	o	o	o	o	o	o																	o	o	o	o	o	o	o	o	o	x
x	x	x	o	o	o	o	o	o	o	o	o															o	o	o	o	o	o	o	o	o	x	x
x	x	x	x	o	o	o	o	o	o	o	o	o													o	o	o	o	o	o	o	o	o	x	x	x
x	x	x	x	x	o	o	o	o	o	o	o	o	o											o	o	o	o	o	o	o	o	o	x	x	x	x
x	x	x	x	x	x	o	o	o	o	o	o	o	o	o									o	o	o	o	o	o	o	o	o	x	x	x	x	x
x	x	x	x	x	x	x	o	o	o	o	o	o	o	o	o							o	o	o	o	o	o	o	o	o	x	x	x	x	x	x
x	x	x	x	x	x	x	x	o	o	o	o	o	o	o	o	o					o	o	o	o	o	o	o	o	o	x	x	x	x	x	x	x

X - 100 Tex wool in dark grey

O - Coloured composited yarn sample D partially filled in the blank area in the pattern

Blank area - 112 Tex wool in white

<u>The design diagram of the pattern on the Shima Seiki SES 122 S knitting machine</u>



A three colour bird's eye jacquard structure

Appendix B.9 The Information of Designs of the Knitted Fabric 4.

<u>The design of the background of the pattern</u>

X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
X																							X					
X																							X					
X																							X					
X																							X					
X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X					
X				X															X				X					
X				X															X				X					
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X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X					
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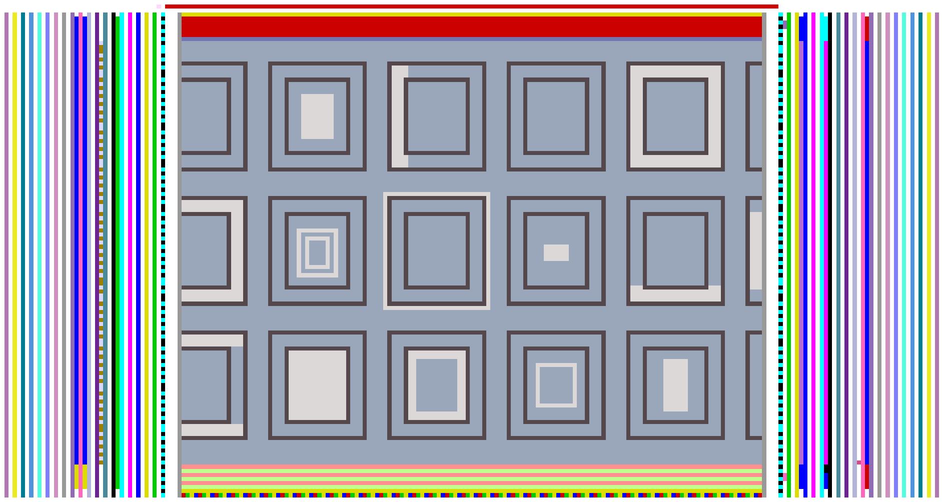
X																							X					
X																							X					
X																							X					
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					

X - 100 Tex wool in dark grey

Blank area - 112 Tex wool in white

O - Coloured composited yarn sample D partially filled in the blank area in the pattern

The design diagram of the pattern on Shima Seiki SES 122 S knitting machine



A three colour bird's eye jacquard structure

APPENDIX C

Appendix C.1 A self-written script of Presentation scenario for presenting the slides in the first part of the experiment.

```
#header

scenario = "10s fabric viewing";

default_background_color = 128, 128, 128;

write_codes=true;

pulse_width=20; # default pulse width =5ms


begin;


#SDL

trial {

  trial_duration = 8000;

  picture {

    text {caption = "Preparing..."; font_size = 30; font_color = 255, 255, 255;

    };

    x = 0; y = 0;

  };

  port_code=2;

  code = "Preparation";

}preparation_trial;      # Preparation screen with a white "Preparing..." at the center


trial {

  trial_duration = 10000;

  picture {

    text {caption = "Eyes Close"; font_size = 30; font_color = 255, 255, 255;

    };

    x = 0; y = 0;

  };

  port_code=2;

  code = "EyesClose";

}eyesclose_trial;      # screen with a white "Eyes Close" at the center


trial {
```

```
  trial_duration = 3000;
  picture {
    text {caption = "Eyes Open"; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "EyesOpen";
}eyesopen_trial;      # screen with a white "Eyes Open" at the center

trial {
  trial_duration = 3000;
  picture {
    text {caption = "Blink Eyes."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Blink";
}blink_trial;      # Blink screen with a white "Blink Eyes Once." at the center

trial {
  picture {
    text {caption = " "; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Interval";
}interval_trial;      # Interval screen with a grey screen display

trial {
  trial_duration = 20000;

  picture {
```

```
    text {caption = "20 Seconds Break."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Break";
}break_trial;     # Break screen with a white "20 Seconds Break." at the center

trial {
  trial_duration = 3000;
  picture {
    text {caption = "Section End"; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "End";
}end_trial;     # screen with a white "Section End" at the center

array {
  bitmap {filename = "1.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric1";}fabric1;
  bitmap {filename = "2.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric2";};
  bitmap {filename = "3.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric3";};
  bitmap {filename = "4.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric4";};
  bitmap {filename = "5.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric5";};
  bitmap {filename = "6.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric6";};
  bitmap {filename = "7.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric7";};
  bitmap {filename = "8.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric8";};
}fabrics;

trial {
   stimulus_event {
      picture { bitmap fabric1; x = 0; y = 0;
           } pic;
      duration = 12000;
```

```
		port_code=1;
		}event1;
}main_trial;

begin_pcl;
#pcl
preparation_trial.present();
fabrics.shuffle();
loop int i = 1 until i > 4 begin
	eyesclose_trial.present();
	eyesopen_trial.present();
	blink_trial.present();
	interval_trial.set_duration(random(2500,3500));
	interval_trial.present();
	pic.set_part( 1, fabrics[i] );
	event1.set_event_code( fabrics[i].description() );
	main_trial.present();
	i = i + 1
end;
break_trial.present();

loop int i = 5 until i > 8 begin
	eyesclose_trial.present();
	eyesopen_trial.present();
	blink_trial.present();
	interval_trial.set_duration(random(2500,3500));
	interval_trial.present();
	pic.set_part( 1, fabrics[i] );
	event1.set_event_code( fabrics[i].description() );
	main_trial.present();
	i = i + 1
end;

end_trial.present();
```

Appendix C.2 A self-written script of Presentation scenario for presenting the slides in the second part of the experiment.

```
#header
scenario = "Self-reported Rating Experiment";
default_background_color = 128, 128, 128;
write_codes=true;
pulse_width=20; # default pulse width =5ms

begin;

#SDL

trial {
  trial_duration = 8000;
  picture {
    text {caption = "Preparing..."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Preparation";
}preparation_trial;    # Preparation screen with a white "Preparing..." at the center

trial {
  trial_duration = 8000;
  picture {
    text {caption = "Please rate the next fabric."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Rating";
}rating_trial;    # Rating screen with a white "Please rate the next fabric." at the center
```

```
trial {
  trial_duration = 4000;
  picture {
    text {caption = "Thank You!"; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Thanks";
}thanks_trial;     # Thanks screen with a white "Thank You!" at the center


array {
  bitmap {filename = "1.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric1";}fabric1;
  bitmap {filename = "2.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric2";};
  bitmap {filename = "3.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric3";};
  bitmap {filename = "4.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric4";};
  bitmap {filename = "5.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric5";};
  bitmap {filename = "6.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric6";};
  bitmap {filename = "7.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric7";};
  bitmap {filename = "8.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric8";};
}fabrics;


trial {


   stimulus_event {
      picture { bitmap fabric1; x = 0; y = 0;
            } pic;
      duration = 30000;
      port_code=1;
      }event1;
}main_trial;
```

```
begin_pcl;


#pcl
preparation_trial.present();


fabrics.shuffle();


loop int i = 1 until i > 8 begin
    rating_trial.present();
    pic.set_part( 1, fabrics[i] );
    event1.set_event_code( fabrics[i].description() );
    main_trial.present();
    i = i + 1
end;


thanks_trial.present();
```

Appendix C.3 Differences of 20 participants' Delta power responding to the Fabric 1 and Fabric 2.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
5.046388	-5.86174	-3.48728	-8.69331	-0.94779	-8.04686	-7.55965	-10.1317	-9.2366	-9.393	-6.55587	9.783179	-8.81602
6.512474	-8.15403	-2.09447	-2.05965	-1.26481	-3.25534	-4.00902	-6.57406	-0.25501	-2.24845	-4.41628	5.390721	-0.8391
2.122727	-2.8026	0.88653	-3.64354	-1.87567	-0.37061	-1.48679	-1.19208	-4.66788	-8.33031	-5.05744	0.988701	-4.76412
-2.06673	-1.04735	-0.10918	2.389054	-0.31244	1.951919	-2.98812	-2.01677	-1.23152	-0.53453	-0.84389	-1.4794	1.26108
-0.68466	-5.97005	0.981719	-4.05827	-0.03321	-4.28776	-4.78691	-6.81681	-3.80903	-2.12422	-0.4217	-1.57902	-3.73945
9.711994	5.108414	2.210127	7.452112	3.839392	2.559419	5.843973	7.183849	12.82727	13.47053	5.261793	8.048992	6.936655
7.478091	5.727152	-1.67256	4.581994	1.192382	8.18949	5.740577	7.944433	4.639878	8.133379	7.772332	5.954536	11.95321
1.769546	1.960872	2.941569	4.29681	1.340552	0.587453	3.415105	5.647119	-2.02754	2.987938	-1.19661	0.930991	-0.94518
6.440599	-1.53954	0.015507	-0.96109	3.296597	-4.30383	3.325039	-0.04003	-3.20648	-0.85939	-7.75153	4.46079	-0.9931
-4.32795	-7.37464	-3.28107	-5.70829	*	-2.08682	-12.6307	-9.88804	-11.2526	-7.61331	-9.44015	-6.32909	-14.4209
1.065314	-8.387	-7.87759	-4.7835	4.037141	-5.77858	-5.2604	-6.15132	-0.62864	-0.93285	-0.50212	-2.24936	-4.71093
-0.52395	1.030427	0.014789	-0.14688	2.97924	-0.9164	3.323415	4.947224	-1.85289	-3.53493	4.830903	-2.59644	6.043769
-3.17863	5.275059	3.244045	3.535408	0.565992	0.723568	7.580147	5.12167	2.706764	-1.64032	3.53556	-5.94883	2.669331
-2.57817	-0.9308	2.652245	-1.8424	-2.97019	1.434183	-1.00611	-3.93991	-1.8666	-3.1513	-5.03804	-8.10246	-1.99159
-4.67437	-3.83985	-1.59347	-2.10997	0.840921	2.114171	-1.85269	-4.17562	-0.93957	-0.20177	5.643029	-5.4081	5.512142
11.50664	6.897338	4.16664	5.763706	6.167909	5.963478	6.799235	7.310023	14.55856	5.944723	-0.56068	6.788164	1.551768
4.858138	-5.28865	-1.45603	-1.00607	5.240066	-1.50191	0.510652	4.733948	0.764501	-1.86276	0.087916	-2.73792	-2.55195
-0.76275	0.948341	-3.56666	-0.86427	-3.21255	-1.35555	-0.46157	-0.77777	0.087421	2.617903	1.061743	3.150158	-1.86373
7.858712	-7.43524	-2.65536	-4.25238	5.488271	-0.12892	2.991035	-2.06052	5.479657	0.167465	0.971658	0.969145	-6.12813
-3.56102	-0.24815	7.468024	-0.30144	-2.68442	5.36872	1.90807	3.024089	4.328694	-3.13026	-3.90247	5.927371	-1.76508

* Odd sample was excluded for the normal distribution of the data.

Appendix C.4 Differences of 20 participants’ Theta power responding to the Fabric 1 and Fabric 2.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
3.0858	3.171	5.38623	0.7119	5.58516	4.07573	-2.67587	0.97107	0.68076	-2.93663	0.36961	12.5449	0.36749
0.3034	-5.2746	-5.45186	0.31959	-3.08287	2.1733	0.76191	-5.03728	0.8868	-5.32913	2.28868	-0.365	9.00414
-5.6668	-3.9386	4.11294	-1.38264	-6.06678	-1.34027	-2.05995	-3.01596	-0.10429	-1.35155	0.61554	-5.4452	-2.50092
-2.8713	-0.5504	3.3057	-0.71824	-6.7213	2.84052	-7.34846	-4.55313	-9.70682	-5.14316	-0.38794	-3.6087	2.13724
5.229	-4.9551	-0.58924	-4.50369	3.44261	-0.79624	2.35942	-1.34372	-2.76107	-2.21697	0.16248	6.0134	-1.27159
1.6078	1.6204	1.58018	2.47657	3.75121	0.29337	1.72848	-4.78507	2.59211	1.25974	-2.28983	-2.2835	-5.59462
-0.8349	-4.6671	-4.54643	4.36857	-2.47541	1.23	-2.45025	-2.89021	-0.08125	1.81598	1.77329	-0.3837	6.50527
1.6107	-2.4871	0.75711	-1.0275	0.28056	-0.88457	-0.49836	-1.00801	-1.33092	-1.47852	-2.05825	3.602	1.401
10.4167	-0.0961	4.36748	-1.84189	-0.53689	-0.15986	1.1781	0.95997	-2.86134	-3.77496	-7.15307	10.3941	-4.75898
2.6287	0.9386	-4.71676	-5.74944	0.74424	-6.18301	3.30653	2.92064	0.54307	-2.05211	1.58572	-4.9091	-4.88901
-8.4754	-2.746	-1.84541	2.41659	-4.82921	3.65528	-8.34194	-3.51414	-7.08109	-5.70519	-6.89785	-0.1474	-1.04324
6.2158	7.3053	-1.23203	1.03011	-5.92394	-0.06656	1.65431	3.98047	-6.92405	0.47853	1.11406	-5.8987	-8.4451
-1.1144	0.6879	3.26604	3.73951	4.93362	2.56013	-2.24979	2.21948	3.53791	4.85056	4.24986	-3.5513	3.35275
1.2672	4.322	1.11304	1.56445	4.63475	-0.25723	2.7115	1.04746	2.91023	2.1251	2.04568	1.5933	0.47679
-2.8108	-1.6343	-5.39737	-1.05514	-1.54907	-5.19781	-5.09708	-2.48583	-2.72038	-2.56068	-1.88826	-0.1168	-1.89968
5.3453	1.0202	-8.83984	0.74828	4.40019	-3.77651	8.40345	6.30365	5.50954	2.80029	3.50059	4.5086	-2.9246
3.6951	-11.333	-8.21571	-7.20751	-2.81164	0.12113	-2.35607	-5.71302	-4.34381	-2.60064	-2.67827	-2.2542	-8.14369
6.2463	7.115	8.7926	7.77676	6.37357	6.15897	6.60291	7.97262	9.01976	*	7.19275	11.1868	4.7614
1.9697	3.5704	1.60017	4.3174	-5.51795	3.79213	-1.41257	3.30332	-3.26252	-1.60175	-1.24654	0.6292	1.72694
-3.4708	5.7002	7.21111	8.39422	4.39326	6.63105	3.2134	2.63106	0.34177	3.6685	5.096	-5.004	9.23041

* Odd sample was excluded for the normal distribution of the data.

Appendix C.5 Differences of 20 participants' Alpha power responding to the Fabric 1 and Fabric 2.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
7.939294	8.002494	10.58156	7.605794	9.017721	3.40303	4.489851	0.288058	4.25797	3.283618	6.709085	*	7.28087
2.487578	4.54016	2.929505	3.805632	2.112342	4.332453	3.76203	-0.24576	4.392421	4.124043	7.901324	0.330532	9.17761
1.255384	7.53038	11.22075	5.819051	-1.56745	4.918957	0.656563	3.893363	-0.38615	1.756115	-1.5695	-0.52295	2.108323
-0.20683	3.151474	0.603037	2.042321	3.857575	0.614268	0.647168	2.287582	3.134452	2.549309	5.83655	0.927469	-1.69624
5.49721	2.448453	4.596721	2.129398	2.282928	4.966689	3.122411	-3.99786	1.045488	-2.97797	0.418209	5.708541	3.316603
1.553984	-2.82892	-2.20814	-0.29584	0.74698	3.177321	-3.89023	2.272109	-2.93652	-0.07035	-0.43077	1.562203	0.893912
-1.70444	-0.47967	0.527413	1.087355	-1.90948	-5.94363	-1.67912	-2.21296	0.357011	-0.42693	0.135107	-3.90919	-1.57085
2.328589	4.614248	2.336656	3.841406	3.103196	2.875696	-0.09555	3.325492	-0.31282	1.602438	1.958912	0.636868	3.602028
-3.92963	-0.87953	-1.32151	-2.4616	-3.11184	-3.34541	-1.86239	-2.90169	-4.75538	-0.70297	-1.58396	-0.01724	-5.34805
0.251239	-3.74819	-0.40001	-8.60524	0.297118	-3.20968	1.472751	-2.47578	0.695787	-3.96359	-2.34477	-3.08062	-9.53662
-5.30503	-2.9716	-3.50428	-1.78855	-2.5994	-0.58868	-1.32445	-0.14138	-5.0853	-4.50147	-0.2074	-4.59225	-2.58736
-0.90674	4.351106	8.581426	3.706897	-2.25336	3.700561	-4.50048	1.270217	-1.08793	0.686718	4.141538	-3.15341	5.909519
-4.24017	0.278199	1.98956	4.292885	6.098724	-0.37684	3.74809	2.880642	6.380717	6.489719	5.099537	-2.36484	0.668542
1.753785	4.682339	3.241932	1.327107	-1.61474	-0.20434	0.466667	1.387483	-0.78969	1.182498	-2.57821	-1.41298	-1.50089
1.083888	4.458752	3.45605	3.277205	4.474725	1.515209	2.268863	5.035427	1.914326	0.784107	1.809766	-0.52032	6.704075
-3.7201	-0.36903	1.537411	0.06207	-3.35794	0.133508	-6.49723	-5.51163	-4.86071	-5.47671	-4.43018	-0.08275	0.229383
1.679123	-2.5651	-1.30876	-3.7532	-0.03455	1.005049	-2.30682	-3.22066	-2.38586	-3.1483	3.280564	3.998628	-0.25187
1.948729	-0.31855	-3.94628	-0.11409	0.455085	-0.29905	0.730196	0.707754	4.183064	4.74865	3.499822	4.564362	-1.01736
-3.91234	-6.58919	-2.80947	-2.49747	1.053419	-1.25051	4.824039	-5.20185	2.735584	7.348545	2.07189	-3.54685	-1.77831
-2.50291	-0.95038	-0.4691	-1.43676	-3.88644	-0.5296	-2.53552	3.688494	-4.51585	-1.0514	-0.79189	-4.29699	1.146898

* Odd sample was excluded for the normal distribution of the data.

Appendix C.6 Differences of 20 participants' Beta power responding to the Fabric 1 and Fabric 2.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
2.476384	-1.56552	-0.72878	-0.63815	0.548889	-1.23698	0.839689	-1.2051	1.747224	0.304085	-1.54459	-0.04657	-1.42549
1.653423	-3.80692	-1.20819	-1.57269	-1.93324	-2.3399	2.85617	-2.46794	0.682746	-1.68226	-2.00232	0.784312	-2.14376
-0.61997	-0.33824	1.946	-0.53822	1.189654	0.951553	1.398652	1.5481	1.494483	2.095166	0.729285	-1.53723	1.37197
3.384172	1.980281	2.951487	3.315382	-0.09457	3.766389	-0.21887	1.56616	0.098246	1.809695	0.879053	1.680027	2.836791
-1.50003	-0.26966	0.963861	1.105315	-1.33725	-2.25949	-0.69351	-1.01384	-2.66985	-1.94745	-1.17664	-3.18263	-0.47272
-2.20131	-0.96569	-2.75429	-1.14632	1.374134	3.110446	-0.11754	0.56693	0.034655	-0.73569	0.498429	-0.46272	0.543878
0.607396	-0.43934	-0.8912	1.598624	-0.1935	0.04006	0.618144	0.834121	1.249969	3.268503	1.324713	0.595809	0.726725
-0.2689	-3.96792	-4.58373	-4.26403	-0.54396	-1.69289	-2.49331	-2.11456	-1.50485	-3.50662	-0.5809	0.797742	-3.99244
1.874011	1.878717	1.986025	1.041608	-1.85366	0.818969	-1.91164	0.166018	-0.02039	-0.33766	-0.09181	-1.82476	0.408505
0.522548	0.197581	2.329843	0.762371	0.34228	2.481297	0.53081	1.303757	0.590672	0.249776	1.17498	2.226994	0.036475
-0.27986	-1.97384	-3.20245	-2.06778	0.367918	-1.58631	-3.6207	-2.16732	0.175276	-1.41036	-0.64146	-1.19855	-0.79336
-1.88481	-2.41397	-0.75468	-2.15327	-0.20371	-2.43722	-0.86172	-0.64169	1.535544	-0.62767	-1.00837	-1.57032	0.773407
0.217416	3.133951	3.273622	0.881181	-0.48804	1.165859	-1.22237	1.576536	-0.16997	-1.00159	0.038284	-1.15508	-0.06952
0.329139	5.85525	3.591494	4.477163	-1.02893	-0.98076	0.244803	1.918895	-0.21369	2.662657	0.539658	1.249955	3.2181
1.3551	-2.41793	-1.24757	-0.45161	1.441258	-0.09151	-0.03517	-0.42986	-0.42793	-0.41056	-0.36824	-1.59819	4.335415
2.25297	0.831611	1.72323	-0.22625	2.214539	2.686219	0.777261	-0.88993	1.835576	1.259602	2.838285	3.525945	2.660751
4.017903	1.945596	1.733382	1.292895	1.503625	-0.12976	4.094333	-0.09091	5.199995	2.514255	-0.44318	4.114654	-0.68618
-0.53954	1.330759	-0.13207	-0.4944	-1.41939	1.587775	-2.1925	0.100639	-1.19208	-1.28759	0.253932	-0.90963	-0.12462
1.490559	-1.20863	-1.05309	-0.60169	1.767224	1.071039	1.416956	-0.52212	2.091253	1.176497	-0.43753	1.072174	-0.08895
-3.93078	-2.87849	0.235176	-2.19634	-1.57402	1.398286	-2.64173	-2.33405	-2.28224	-1.97897	-2.34021	-2.2508	-1.36228

* Odd sample was excluded for the normal distribution of the data.

Appendix C.7 Differences of 20 participants' Gamma power responding to the Fabric 1 and Fabric 2.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
0.418847	-0.66811	-0.63586	-1.00143	0.411482	-2.3113	-0.09917	-0.7638	-0.02572	-0.77648	-0.00526	0.64444	-1.55092
-0.22814	-1.53629	-2.46755	-1.44496	-0.85809	-1.96734	-0.35848	-0.14422	0.126766	-1.35398	-3.49112	-1.27356	-1.12076
1.701706	-0.3977	0.873416	-0.54061	3.194808	0.416124	1.199941	0.174034	1.563292	0.850299	0.775215	0.396544	0.120705
-1.69483	-2.15354	-1.69231	-1.71984	-0.18901	-2.05862	-2.0049	-1.04138	-1.19393	-0.92686	-0.37787	-1.18739	-1.21838
-2.3193	1.276448	1.369026	1.699301	0.463543	0.498872	0.194216	1.513525	0.785796	1.734333	0.168335	-2.24379	1.902723
1.122468	1.88743	4.859575	2.230258	-0.95126	2.178039	3.603728	2.042664	2.087812	1.903055	0.760084	1.069412	0.37779
0.487869	-3.14895	-2.20814	-1.40787	1.588353	-1.42538	0.583281	-1.2171	-0.1619	-0.3882	1.030217	0.005414	-0.47139
-0.16032	2.170895	0.475994	0.923769	1.382924	-0.22074	1.155318	0.715607	0.85047	1.323021	5.652456	1.257467	-0.97564
-0.4585	0.462779	1.835438	1.882474	1.361457	1.444929	2.055518	1.727661	0.786716	2.641702	1.377712	1.530977	0.863103
-0.60805	-1.09339	-2.23606	-0.79998	-2.21835	-1.30115	-1.44561	-0.97097	-1.57169	-1.3911	-1.92834	0.905537	-0.73451
0.301626	-0.6963	1.121772	1.809106	-0.38901	1.651088	-5.69853	-1.91025	-2.06496	-0.51423	2.830432	-2.69983	1.429107
-0.69023	1.7788	1.861105	2.818627	3.426801	2.077639	3.507037	3.506037	3.901577	3.662124	2.87088	1.386967	1.631401
0.33433	-2.001	-3.03031	-0.53972	-0.07956	0.234081	0.936644	2.741044	0.349159	-0.42507	1.199054	-0.43142	0.967315
0.589894	1.781127	0.38685	1.925726	0.415192	2.085049	0.592338	0.708771	1.155697	0.677061	2.399305	0.777228	2.513361
0.971974	-0.03182	0.083813	0.845896	1.950204	1.905116	0.23232	-0.05348	0.314772	0.965137	0.585608	-0.14746	5.123547
0.08194	4.26398	1.427544	4.059127	2.015246	2.686127	-1.36106	0.896454	0.671839	2.120952	1.403523	0.974681	0.558176
1.58189	-1.18053	-2.00836	-2.70168	0.987288	-0.5561	-0.64001	0.573438	0.191954	-0.73736	-1.29479	2.773386	-1.60718
-1.89839	0.085892	1.681105	0.528673	-3.21486	0.769751	-3.0895	-0.72773	-2.20047	-2.11408	-1.56978	0.149592	1.313427
-1.93971	0.532906	-2.36397	1.062624	-1.60168	-2.11565	4.05561	0.520466	0.667604	2.59099	-1.72012	0.759714	1.642668
2.338164	4.631108	5.413576	5.320861	1.600435	5.316872	1.664	4.321016	3.021901	5.489048	6.649401	0.395573	4.249896

* Odd sample was excluded for the normal distribution of the data.

Appendix C.8 20 participants' Frontal Alpha Asymmetry index to the Fabric 1.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
4.42223	8.92539	-4.50316
3.82967	1.37223	2.45744
3.93943	2.18939	1.75004
-0.4013	0.75155	-1.15285
2.71007	2.85722	-0.14715
-1.97997	1.95595	-3.93591
-0.7563	-0.93774	0.18144
4.8583	2.77243	2.08587
-0.89837	-0.13802	-0.76036
2.21878	3.06409	-0.84531
0.74922	-0.71922	1.46844
2.02532	0.29962	1.7257
0.73348	1.69782	-0.96435
4.08131	3.24956	0.83175
1.24492	1.30608	-0.06116
2.84063	5.5834	-2.74277
2.94391	4.84359	-1.89968
2.4508	1.85587	0.59494
3.38988	3.4567	-0.06682
-0.69033	-0.28748	-0.40284

Appendix C.9 20 participants' Frontal Alpha Asymmetry index to the Fabric 2.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
-1.55363	-2.14436	0.59073
0.04381	-0.39474	0.43855
3.7668	2.81636	0.95044
-0.06736	-2.09732	2.02996
-2.03342	-1.75115	-0.28227
-1.37733	0.29392	-1.67125
2.17421	2.18833	-0.01412
2.94276	0.59023	2.35253
2.42501	-0.41767	2.84268
1.73208	3.61357	-1.88148
2.80461	2.49162	0.31299
4.08972	2.41488	1.67485
0.51829	-1.0413	1.55958
2.46022	3.30344	-0.84322
-0.7557	-0.25377	-0.50193
9.07098	5.8172	3.25378
1.79914	3.76515	-1.96601
2.32938	0.28106	2.04832
3.49575	4.38962	-0.89387
2.31547	3.87434	-1.55887

Appendix C.10 20 participants' heart rate changes (bpm) on each second window when responding to the Fabric 1.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	-0.08081	1.308537	0.374497	-2.96049	-1.21613	-0.32501	-5.11154	-3.01865	-3.6625	-4.3747
2	-4.6818	*	*	-7.63084	-7.26259	-4.07317	-4.05435	-3.56887	-1.1271	-3.17184
3	0.205867	1.457607	0.465463	-0.57285	-0.57888	1.056055	-0.46261	-2.20587	-1.60789	1.705476
4	-1.34379	-0.1103	0.652007	-0.58779	1.632011	2.12662	-0.03375	-2.03711	-0.0068	-1.01717
5	4.874275	3.995453	2.946552	2.22866	2.572186	1.470985	0.877849	-0.96985	-1.43763	0.436829
6	0.797144	1.165982	0.373952	-0.16127	-0.51312	-0.88984	-1.64306	-1.64306	-1.40716	-0.71128
7	1.379115	1.905984	5.150571	3.868257	1.809178	0.612416	-0.17194	3.535678	0.704611	-2.71747
8	0.740818	3.068075	2.009836	0.518235	-1.05381	-0.04539	-1.40279	-3.13905	-2.97332	-0.27504
9	1.131238	0.884899	0.647464	1.93763	2.332534	0.353006	-0.25588	1.049926	0.970062	2.282606
10	2.492342	1.725474	1.156127	2.276171	2.07767	2.180267	4.67319	5.144545	5.144545	3.988132
11	0.435701	-2.96071	-0.87928	-6.93874	-11.2416	*	*	-7.00112	-5.51441	-6.45112
12	2.973766	1.078835	2.736427	7.561673	9.303651	2.909093	-0.94567	-2.9493	2.08329	-0.91442
13	2.823494	-0.43126	-1.61198	0.697711	-2.41231	*	*	2.222195	1.767616	4.425134
14	2.426333	5.365601	2.886568	5.26154	9.335797	8.306171	6.069797	7.163557	*	5.816134
15	0.568529	-3.34427	-3.28245	2.116306	0.063307	-1.35242	-0.05334	1.194785	-0.02658	-0.88536
16	0.880962	0.90691	0.146447	1.327377	0.583931	-2.50431	-2.46629	1.416837	2.996845	3.064237
17	-1.71025	-2.36353	-0.96126	-6.73359	-10.3547	*	-4.13935	-2.64775	-4.06234	-5.60789
18	1.174723	2.624221	0.470043	-0.05733	0.502202	-0.72395	-1.64184	-1.31698	0.172406	-0.58831
19	*	0.974056	1.66915	-3.52867	-3.41198	-5.89791	*	*	*	*
20	0.200716	0.200716	1.082321	0.41002	0.373266	0.90472	1.344613	1.129117	0.612459	0.57997

* Odd sample was excluded for the normal distribution of the data.

Appendix C.11 20 participants' heart rate changes (bpm) on each second window when responding to the Fabric 2.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	-1.41942	-5.90971	-6.70151	-6.99143	-5.02019	-8.30581	-6.5656	-7.98004	-9.31088	-9.30562
2	-3.85111	-3.31068	-3.42837	-5.57342	-4.4951	-2.52854	-3.62702	-5.16813	-2.48338	-6.32426
3	-2.06475	-3.92263	-3.5305	-0.97227	-0.09017	-0.84501	-0.32251	2.737124	3.421576	0.762925
4	-3.76737	-6.31843	-5.97663	-2.8058	-2.66197	-3.597	-2.56833	-3.4716	-5.73707	-6.86496
5	1.532426	0.640635	-1.17974	-1.12657	-0.61005	2.660802	1.608346	1.07557	-0.95594	-3.29454
6	-3.1447	-2.71573	-2.76579	-3.86522	-3.43807	-1.89442	0.485927	0.113199	-1.53615	-2.62449
7	-4.59707	-4.53276	-5.87041	-5.8064	-7.46563	-8.54617	-10.7527	-8.96978	-6.29928	-4.37525
8	-1.20764	-1.75608	-3.04443	-3.26101	-1.67606	-0.83303	-0.07617	-1.01374	-0.26707	-0.20513
9	-2.15729	-4.53456	-4.27451	-3.26894	-2.68818	-3.56168	-3.0684	-2.46973	0.115306	0.259141
10	-2.09473	-0.59265	-3.02626	-4.37329	-2.07271	-2.54362	-3.52507	-0.05763	0.157016	-1.66944
11	-5.00894	-3.18498	-5.29167	-8.49948	-6.51247	-0.62342	-1.46819	-2.83769	-1.00651	2.501113
12	-0.20628	-2.01431	-2.1212	-6.22034	-4.67288	-4.71409	-6.01131	-7.80146	-8.39918	-5.87608
13	2.768833	2.958985	1.642767	0.869559	2.02999	7.521681	3.629034	4.475262	1.720661	3.08859
14	3.298403	5.563857	1.308679	-1.90409	-3.41201	-2.20867	-2.4752	-1.95009	0.426928	2.464874
15	-0.71302	-1.28381	2.512992	-1.19839	-3.53787	0.043967	1.617002	-2.76378	-2.12145	2.063594
16	3.20637	2.146041	1.222446	-0.84215	-0.15819	0.692019	0.210864	0.018749	-0.91902	-1.82649
17	-11.4876	*	*	*	-9.51002	-9.24372	-9.36454	-10.1003	-6.38397	-1.92219
18	-1.65358	-0.7124	-1.00902	-2.13053	-2.59367	-2.00006	-3.51367	-3.69234	-2.65148	-3.70807
19	3.888241	-6.9011	*	-7.37869	-7.48242	-6.0535	-1.46679	-19.3243	*	-11.1883
20	0.425367	-3.78203	-7.58139	-6.58842	-5.23115	-4.67953	-6.20816	-7.70036	-7.48488	-5.21824

* Odd sample was excluded for the normal distribution of the data.

Appendix C.12 20 participants' differences of heart rate changes (bpm) in responses to the Fabric 1 and Fabric 2.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	1.33861	7.2182	7.076	4.0309	3.8041	7.9808	1.4541	4.9614	5.6484	4.9309
2	-0.83068	-5.182	-3.3075	-2.0574	-2.7675	-1.5446	-0.4273	1.5993	1.3563	3.1524
3	2.27062	5.3802	3.996	0.3994	-0.4887	1.9011	-0.1401	-4.943	-5.0295	0.9426
4	2.42358	6.2081	6.6286	2.218	4.294	5.7236	2.5346	1.4345	5.7303	5.8478
5	3.34185	3.3548	4.1263	3.3552	3.1822	-1.1898	-0.7305	-2.0454	-0.4817	3.7314
6	3.94184	3.8817	3.1397	3.7039	2.9249	1.0046	-2.129	-1.7563	0.129	1.9132
7	5.97619	6.4387	11.021	9.6747	9.2748	9.1586	10.5808	12.5055	7.0039	1.6578
8	1.94846	4.8242	5.0543	3.7792	0.6223	0.7876	-1.3266	-2.1253	-2.7063	-0.0699
9	3.28853	5.4195	4.922	5.2066	5.0207	3.9147	2.8125	3.5197	0.8548	2.0235
10	4.58707	2.3181	4.1824	6.6495	4.1504	4.7239	8.1983	5.2022	4.9875	5.6576
11	5.44464	0.2243	4.4124	1.5607	-4.7291	-12.3248	-10.3549	-4.1634	-4.5079	-8.9522
12	3.18005	3.0931	4.8576	13.782	13.9765	7.6232	5.0656	4.8522	10.4825	4.9617
13	0.05466	-3.3902	-3.2547	-0.1718	-4.4423	-25.0381	14.4272	-2.2531	0.047	1.3365
14	-0.87207	-0.1983	1.5779	7.1656	12.7478	10.5148	8.545	9.1136	12.9611	3.3513
15	1.28155	-2.0605	-5.7954	3.3147	3.6012	-1.3964	-1.6703	3.9586	2.0949	-2.949
16	-2.32541	-1.2391	-1.076	2.1695	0.7421	-3.1963	-2.6772	1.3981	3.9159	4.8907
17	9.77732	17.8758	18.2366	8.2116	-0.8447	-0.7749	5.2252	7.4525	2.3216	-3.6857
18	2.82831	3.3366	1.4791	2.0732	3.0959	1.2761	1.8718	2.3754	2.8239	3.1198
19	-9.86396	7.8752	17.638	3.85	4.0704	0.1556	-13.8119	1.907	3.4348	-11.2263
20	-0.22465	3.9827	8.6637	6.9984	5.6044	5.5843	7.5528	8.8295	8.0973	5.7982

* Odd sample was excluded for the normal distribution of the data.

Appendix C.13 19 participants' self-reported rating scores to the Fabric 1 and Fabric 2 on the Valence, Arousal and Likert scales.

Participant	Rating Scores on Valence Scale to Fabric 1	Rating Scores on Valence Scale to Fabric 2	Difference of Rating Scores on Valence Scale	Rating Scores on Arousal Scale to Fabric 1	Rating Scores on Arousal Scale to Fabric 2	Difference of Rating Scores on Arousal Scale	Rating Scores on Likert Scale to Fabric 1	Rating Scores on Likert Scale to Fabric 2	Difference of Rating Scores on Likert Scale
1	1	0	1	1	-2	3	1	-1	2
2	-2	0	-2	2	0	2	-2	1	-3
3	2	2	0	2	2	0	2	2	0
4	-2	-1	-1	2	2	0	1	1	0
5	-4	4	*	0	3	-3	-3	3	-6
6	2	2	0	2	2	0	0	3	-3
7	1	1	0	0	1	-1	0	1	-1
8	-2	0	-2	-2	2	-4	-3	-2	-1
9	-1	-1	0	-1	1	-2	0	-1	1
10	-2	-1	-1	-4	-2	-2	-1	-1	0
11	-1	0	-1	-1	1	-2	-1	0	-1
12	-3	1	-4	3	3	0	-2	0	-2
13	-2	0	-2	-3	0	-3	2	0	2
14	-3	-3	0	3	3	0	-3	-3	0
15	3	3	0	2	2	0	2	2	0
16	4	3	1	3	3	0	3	4	-1
17	2	2	0	1	2	-1	2	2	0
18	-1	-1	0	-1	-2	1	-1	-3	2
19	0	-1	1	-2	0	-2	-1	0	-1

Appendix C.14 Differences of 20 participants' Delta power responding to the Fabric 3 and Fabric 4.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
0.247785	-5.8591	-7.41547	-4.21325	-4.46366	-6.48118	-5.47447	-3.2752	-5.9343	-2.99927	-1.70147	-7.13171	-2.29094
0.975941	8.645908	2.71121	3.525282	3.505409	3.556005	3.094076	2.088448	1.587409	0.218736	-0.84845	-1.74198	2.221607
0.123869	-1.78959	-3.21995	-1.76989	3.066365	-4.87111	-0.60955	-2.18937	-0.2693	-0.06257	1.566302	0.417641	-0.90148
-5.57084	1.141661	1.128241	3.705663	10.15808	4.666167	9.771451	5.665752	8.076705	6.742617	2.891455	-2.5803	4.276358
10.38962	-3.67554	-7.28324	-6.11883	11.88264	-6.39658	10.95759	-0.18988	10.67232	8.903777	4.01941	7.9364	0.870804
8.748314	-1.40077	-0.39447	-0.25901	4.330049	-1.37909	-3.35404	-3.95553	-5.25889	-2.32937	0.467988	0.921234	0.691
8.410845	-4.25553	-2.89673	-2.64095	-6.76266	2.508268	-2.04439	-7.56772	-5.71173	-10.6919	-1.75416	6.215136	-2.12745
-1.90326	1.830138	6.72712	0.170754	-5.62968	5.130923	-1.60305	2.786025	-4.07629	-1.99654	-0.53562	-1.34997	2.912604
9.405792	1.959732	5.89652	4.628264	4.820587	8.459297	9.509182	4.617995	6.854763	6.25907	2.827209	*	4.521193
7.057496	2.279156	-4.66246	1.99523	4.101698	-3.61064	10.45604	8.772167	8.018224	5.235574	*	5.296662	1.220178
-1.75877	-6.31102	-0.42593	-6.74866	-4.06312	-2.57712	-2.93899	-6.42098	-8.41875	-8.09039	-2.04865	-0.6961	-7.66954
-4.04956	8.859118	3.148783	9.882859	12.82987	3.330562	10.4484	7.434717	9.274356	5.036187	*	-8.79515	13.41886
2.199375	5.614334	3.713543	2.708228	12.08406	3.871676	10.12314	6.842347	8.582752	4.111984	2.209903	-0.43412	1.807599
5.297272	6.294315	7.405937	8.666021	8.548797	6.838512	7.492228	10.14883	9.747397	8.539811	*	11.69406	11.03599
3.14654	2.172779	2.372017	0.704273	-4.49592	3.318141	1.94406	0.206263	2.660016	-2.50016	0.595465	-1.37103	-4.82255
0.797198	-10.3235	-7.37519	-8.18584	4.94569	-6.64227	-3.77744	-10.4421	0.024063	-2.38313	-0.85393	-0.8147	-9.08977
1.480316	-0.41465	1.04336	-1.1656	7.98538	-5.84301	5.776763	5.186247	6.694616	-0.71111	3.357927	2.659068	0.196726
-2.32504	2.054915	4.006226	4.616218	-2.44248	-0.39411	0.198182	-2.22543	1.841307	5.631239	-0.40931	3.008153	4.556942
2.804693	-2.26221	-0.69607	-2.98359	1.255824	0.192131	0.627767	-1.35257	3.326793	-2.60572	-1.15853	5.409066	9.828064
-2.53961	1.255065	4.862319	3.20829	2.954304	6.208153	2.654076	2.000229	2.721886	2.819564	3.252164	2.119394	4.143458

* Odd sample was excluded for the normal distribution of the data.

Appendix C.15 Differences of 20 participants' Theta power responding to the Fabric 3 and Fabric 4.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
5.22894	1.814885	1.035108	0.737344	1.815096	1.889942	7.815181	4.859193	3.962175	4.434724	5.916493	2.765097	2.949139
-0.56183	0.737451	0.802712	3.497014	-3.53662	-2.04701	-1.37362	-4.14119	1.618937	2.738756	1.557317	-2.59759	2.802488
2.131545	-3.52553	-3.83083	-3.3149	2.632443	0.116908	2.862813	0.349066	7.49741	2.324306	-5.15845	4.469834	-1.95372
-8.53974	-2.15599	-1.90655	-1.45905	-5.75784	-1.41394	-5.93626	-3.03458	-3.62401	-1.6152	-5.4294	-8.31643	-4.20591
-4.04745	1.345485	-1.30808	1.936341	-4.2742	5.357384	-2.4455	1.434545	-4.89868	-6.12079	-3.35244	-4.02578	8.030622
3.897589	6.588784	5.183721	4.037724	1.010825	2.156755	2.012194	5.953396	-0.16227	4.809909	5.972214	1.623138	4.100147
4.918332	-0.02976	0.48213	1.032068	-5.6809	-0.11424	-2.77535	-2.09633	-1.53524	1.488464	-3.07728	3.336916	1.240042
6.31941	-4.23166	-0.30128	-3.52262	-0.43966	-2.41211	1.747412	0.220369	-1.58554	-0.93449	-0.46596	5.432875	-6.3257
10.26025	0.394911	2.495723	3.5417	6.424619	3.082922	-1.00791	1.575455	4.254635	7.103873	1.959553	14.49849	3.358179
2.587369	6.839847	4.689269	4.287742	4.666955	1.156207	3.437255	4.457637	3.749647	4.803178	2.970012	3.785266	2.545721
2.95523	8.892544	7.282806	7.47499	1.235519	5.883015	2.441977	7.993611	1.017377	4.619545	3.117983	-2.4896	5.61296
-10.7344	2.739746	-2.23332	0.747439	-1.42066	2.185869	-0.96554	3.524325	-0.54857	-0.4159	-8.31721	-1.25228	0.512444
-1.76141	3.120659	2.166352	8.270975	8.161041	8.781073	9.226668	6.887883	10.92545	7.924679	4.93524	-2.50903	8.655684
1.174927	9.661956	8.993045	8.14055	1.140071	6.413065	5.882965	7.751938	4.006098	4.007356	3.133285	0.185327	5.82709
3.456921	2.977501	-2.99362	2.87957	1.671302	-4.70646	5.707786	7.053132	6.428379	3.072282	-1.16269	4.725169	-3.97633
0.440075	0.125582	2.904939	0.613271	1.100266	3.979527	1.705711	-1.65082	-0.83361	-0.39843	2.913632	-2.1037	3.34136
-0.97252	8.824911	10.88794	7.305385	5.811166	8.615131	7.348882	4.706982	3.927163	3.264782	2.827124	-0.74332	7.474435
-1.95151	-1.86882	-0.19723	-0.31158	-7.98099	-2.69216	-4.10135	-0.77703	-10.5471	-5.24851	-7.38234	-3.4881	-5.64642
7.23072	14.6904	7.42334	14.14156	8.030306	5.549715	12.0438	11.69596	7.039862	13.13879	9.387014	5.612819	16.59014
0.719406	-4.78367	-3.28199	-6.97629	-4.03139	-3.04031	-1.27257	-3.20474	2.154394	-6.68768	-7.2038	3.593255	-3.14868

Appendix C.16 Differences of 20 participants' Alpha power responding to the Fabric 3 and Fabric 4.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
3.827145	0.24895	1.862634	-4.00005	0.057019	-6.32164	1.977969	1.771617	-0.84719	-2.58911	-3.37263	0.71427	-6.5657
-2.07669	2.41742	-4.27503	4.086273	-2.32307	-0.66282	8.734616	12.20832	7.83409	3.017422	-4.21068	-2.65626	-0.27947
-4.39447	-2.87674	-5.18162	-2.31058	-0.23747	-6.71831	-3.78895	-3.77046	-2.21085	-1.63076	-1.72062	-1.3725	-3.71589
2.962211	-0.12663	-2.87563	-0.93206	2.792672	-4.36577	1.728765	2.802926	1.636713	0.509193	-0.25154	-0.83078	-4.77246
-5.23861	-7.93807	-4.48572	-3.42378	0.758176	-3.56814	-0.35348	-0.46214	-0.77668	-1.51685	0.975669	-5.33475	-2.97181
6.117713	0.242482	0.170554	-1.10608	4.924815	0.986091	2.602049	-1.86913	2.514589	2.588196	1.159152	7.090366	-2.87421
1.515101	1.343739	2.134681	-2.31331	-3.21169	-1.44202	-2.143	-1.05108	-2.39108	-0.78595	-4.74142	-1.51432	-0.93172
4.761744	6.879428	7.074378	7.566248	6.281337	6.92861	2.786332	5.963479	5.659582	5.864777	9.39043	5.433463	9.140724
3.22775	5.342198	2.727423	3.867363	3.958372	1.424305	5.520798	4.639859	4.526447	2.912131	-0.24317	7.120481	2.136099
1.381741	-5.97542	-4.05152	-5.4125	2.323106	-3.16455	3.527829	0.222812	1.595164	1.614455	1.804129	-0.93548	-2.50325
-4.16446	7.655388	5.112515	5.833974	-0.58177	4.677077	-5.3967	2.671605	-3.38569	-0.30355	7.080521	-1.95666	5.318
-3.6426	2.001295	-0.16448	-0.7133	-1.37723	-2.32662	0.353812	8.142019	1.045575	1.363855	-3.55978	2.719166	-0.14197
9.90487	5.30131	5.335765	7.47961	4.207125	7.109912	-1.42705	2.10287	0.242021	2.558703	4.362206	7.501648	5.773812
-0.56834	1.890116	6.631216	2.020442	-6.3352	6.174052	-0.32743	-1.55824	-4.42083	-1.94707	-3.93846	-5.38957	1.462461
0.072082	-1.9324	0.974958	-2.11771	5.933972	-2.19489	0.967229	-3.53276	2.215891	0.633431	-1.68026	-3.7667	0.815782
3.274453	0.53065	-0.73899	0.301624	-0.13538	1.825312	3.769671	0.901362	1.435553	-1.1845	-0.36545	2.011282	0.785955
-2.80212	-2.71782	-3.8753	-1.63181	1.276323	-2.90405	2.952437	-1.22288	2.276977	-0.70303	0.56143	-2.36027	-4.24463
1.938877	8.124443	-0.71275	5.68086	0.810372	1.015563	0.872176	6.025229	0.988256	3.62123	4.526813	2.062771	2.472501
1.283428	4.249101	7.57171	0.421817	0.132989	4.322425	4.893801	-3.64396	1.122917	-0.16016	1.158911	-1.40258	5.71529
0.895037	4.796553	5.713196	7.869166	2.631273	5.048084	0.179897	0.20629	2.697414	4.343151	6.943081	3.499327	6.620623

Appendix C.17 Differences of 20 participants' Beta power responding to the Fabric 3 and Fabric 4.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-0.05938	0.400069	-1.58159	-1.55141	0.007261	-1.68756	0.715803	-0.0104	0.858429	2.35636	2.830946	-0.5319	-0.32544
-0.29537	-0.1901	-1.45809	1.432442	1.718812	-0.77595	2.314212	2.591261	2.537155	2.405414	2.165443	0.571243	2.142915
2.509477	-2.11682	-2.10311	-2.68591	0.995454	-1.62552	1.036835	0.195638	1.513525	-1.76723	0.593399	4.072279	-2.25242
-0.42989	-1.49388	-1.00826	-3.16403	-4.15873	-0.92718	-3.10008	-2.54662	-4.69539	-5.01513	-3.63462	-5.20013	-3.53889
-1.3346	-1.23249	-1.66386	0.013583	1.130331	0.7177	-2.64621	1.481847	1.846279	2.086556	2.606618	0.077536	-0.92236
-0.99847	-0.15528	1.432411	1.044286	0.05676	0.04072	0.501744	1.816152	0.834766	2.418343	-0.05243	1.453901	0.925916
-0.39826	-1.73021	-1.12198	-1.83763	3.0713	1.193933	1.482511	-1.01105	0.449711	-1.53139	2.50355	-1.83534	1.638054
1.871044	2.196269	1.471839	1.244872	0.183898	1.305946	2.161346	1.963891	2.225613	2.023113	2.365843	3.777265	0.888189
0.141356	0.641192	0.59873	-1.10039	0.758815	-0.95877	-0.19857	-0.33865	0.228004	-1.06956	-1.74107	5.226378	-2.22812
-2.15776	-4.25949	-3.68847	-4.1524	-2.53319	-1.31499	-1.29985	-3.61486	-2.52595	-3.33859	-5.02006	-1.7343	-4.75409
1.530239	-1.92044	-2.98057	-0.67187	0.689811	-0.98293	-0.04334	0.221482	-0.05524	-1.1745	0.703776	1.546984	-1.22046
-3.25434	1.84577	-0.85445	1.450871	-2.79335	1.121099	-0.55135	0.860044	-1.71899	0.435632	1.115818	1.451336	0.879991
4.404951	1.071506	-0.10021	2.47262	-0.5432	-0.0845	4.145147	3.221206	2.837456	2.604251	-0.56158	2.447663	1.132079
0.861959	0.33756	1.879085	0.792287	1.484071	*	-0.77016	-0.17913	-0.44689	0.870341	1.174884	0.790058	1.86025
3.841106	3.843967	2.187484	5.086137	6.548581	*	5.803154	5.593546	7.115945	5.213643	5.200301	5.003931	*
0.210663	-0.68362	0.157994	-3.22075	-3.06608	-1.77684	1.110383	0.34328	-1.87133	-3.05523	-1.7163	-1.59354	-3.09698
-1.92818	-3.18317	-1.90276	-4.03842	-2.40275	-1.77323	-3.94096	-3.3632	-2.31289	-2.13917	0.567001	-1.80131	-0.94073
-2.11505	0.979115	-2.13893	-0.73419	0.855765	-1.52852	-0.53563	-0.2609	-0.22792	-1.06465	-1.10224	3.903015	-1.29713
-1.12493	-1.50327	1.132094	-1.46143	-2.10139	0.800761	0.233574	-2.27122	-0.39658	-0.466	-0.67767	-3.2297	-1.01644
-0.39247	4.509677	5.272607	4.090448	1.077768	*	0.594479	2.300641	1.288274	3.735035	-0.40692	-2.91723	4.304

* Odd sample was excluded for the normal distribution of the data.

Appendix C.18 Differences of 20 participants' Gamma power responding to the Fabric 3 and Fabric 4.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-0.66764	-1.71429	-0.87325	-2.05222	-0.53092	1.284829	0.088568	-0.91592	-0.82801	-0.68578	-0.23168	-0.89666	-1.36436
-2.69813	0.381794	0.268202	-0.84399	0.294354	1.053173	-2.50032	1.577791	-1.28563	0.475386	-1.99121	0.212094	-0.54509
-0.22764	0.445469	-0.60242	-0.19129	-1.47322	-0.60534	-0.70511	0.890545	-1.84117	-2.8556	-2.07663	1.094425	-1.32435
-0.78536	1.285167	0.920989	0.200079	-0.27814	0.902821	0.230634	0.456189	0.426903	1.291965	-0.2319	-6.40373	0.426027
-0.8423	-1.22139	-1.93085	-1.84307	-0.51155	-0.43632	-0.81595	-0.31674	-0.53862	-0.36838	-0.15805	0.726483	-0.88185
-0.81992	-0.57792	-0.90683	-0.87463	-3.97083	-2.14166	-1.78984	-0.09215	-2.14466	-1.8692	-0.73796	-0.00635	-1.15013
-1.55143	1.448262	0.172629	2.55558	0.79997	0.339217	-1.02543	-0.7172	-1.93241	-0.18553	1.005936	0.49638	*
0.525798	-0.39314	0.496912	0.526022	2.981049	1.531476	0.224888	-0.9821	1.244981	0.500778	1.180148	2.003274	0.859044
-2.2707	-0.03392	-0.45426	-0.11014	-0.493	-2.88602	0.812909	-0.14322	-1.09099	-0.58119	-0.38942	-0.24317	-1.17032
-0.21738	3.076535	1.303615	1.757934	1.18549	0.731425	2.036637	1.002844	1.545213	1.701238	0.135917	2.979568	0.722604
-0.91439	0.155027	-1.53255	-1.00581	0.073229	-1.99646	-2.82875	-0.39559	-2.21522	-0.20714	0.56088	-0.73909	-1.33117
-1.7327	0.885539	2.865576	0.242814	-2.02287	0.047433	0.611519	0.236048	-0.55116	-0.2107	-0.97755	-2.31512	-1.02632
3.689798	0.405972	3.279545	-0.70415	-1.04938	1.861965	1.2922	-2.77235	-1.31677	-1.22863	-1.88357	1.564558	-0.33481
0.524684	1.15685	1.81647	0.881437	1.18354	1.95066	0.072453	1.302858	0.881235	0.62883	-0.44932	-0.70879	-0.21603
1.39877	2.648733	3.019256	3.92273	4.0729	2.978161	0.409467	2.384231	1.827981	1.934546	2.943777	3.734329	*
-1.73693	-0.28603	0.658421	-0.0459	-1.79165	1.009452	-0.31334	-1.81305	-1.4046	-0.08166	-0.05049	-1.18549	*
1.49606	0.349571	0.586237	-1.71969	1.275622	-0.15307	2.953366	2.346154	3.925083	0.395843	1.630262	-1.09781	-0.15287
0.902605	4.870483	3.810975	3.478613	1.258609	3.343238	3.276136	4.101765	2.531962	3.165887	1.589644	2.359645	*
1.415034	2.32857	0.434086	1.748389	-1.25297	0.053093	2.729605	1.684719	0.883019	2.572593	-0.63299	-2.40019	0.524069
-0.44451	3.546769	6.486444	5.636776	0.458156	2.338495	-0.00138	2.955529	1.221744	4.56951	*	-1.37252	*

* Odd sample was excluded for the normal distribution of the data.

Appendix C.19 20 participants' Frontal Alpha Asymmetry index to the Fabric 3.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
5.32025	4.70551	0.61474
2.51365	1.61236	0.90129
0.58597	2.88129	-2.29532
4.70539	2.88538	1.82001
2.02864	2.22839	-0.19974
2.35831	3.80155	-1.44324
1.29908	0.90429	0.39478
3.75292	4.55017	-0.79725
6.48478	2.8114	3.67338
1.71594	0.54952	1.16643
-1.39152	1.38808	-2.77961
0.01302	1.12409	-1.11107
2.63175	6.16169	-3.52993
2.77507	4.00318	-1.22811
2.24847	4.43888	-2.19041
2.50492	0.34718	2.15774
0.35119	1.40091	-1.04972
3.35528	4.12853	-0.77325
7.24739	4.22336	3.02403
-2.15724	-1.0199	-1.13735

Appendix C.20 20 participants' Frontal Alpha Asymmetry index to the Fabric 4.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
2.42111	4.5583	-2.1372
-1.33822	3.54929	-4.88751
3.38369	2.83543	0.54827
1.18334	1.00944	0.17391
4.82736	3.36259	1.46478
-2.66398	-2.34948	-0.31451
1.94871	4.11558	-2.16686
2.40233	0.1291	2.27323
2.42025	-2.25339	4.67364
-0.41748	1.14025	-1.55773
3.1906	2.17381	1.01679
0.03509	0.08262	-0.04753
-0.32891	0.00736	-0.33627
2.24303	7.48297	-5.23995
2.50618	1.65193	0.85425
-1.2151	0.76873	-1.98384
0.53584	2.16182	-1.62598
2.14966	2.20842	-0.05877
4.21713	3.06058	1.15655
-3.41828	-3.99394	0.57566

Appendix C.21 20 participants' heart rate changes (bpm) on each second window when responding to the Fabric 3.

Participants \ Time Window	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	1.508966	0.031553	-0.52531	-0.32858	-1.384	-0.21868	0.357526	-0.68334	1.851338	-1.75492
2	-3.20626	1.134431	4.95391	3.329207	4.484937	4.959429	-0.56526	-4.73777	-2.49489	-3.24177
3	3.053347	1.555074	0.321582	1.932724	4.314335	2.671725	1.550126	2.68178	5.320686	6.166006
4	-2.15855	-0.31833	0.703972	0.586865	1.708598	1.225062	-1.3933	-1.04892	-0.72278	-2.0328
5	4.461304	2.186712	-1.1575	-6.07887	-7.9667	-8.68056	-7.14774	-3.30614	-5.21924	-7.1654
6	-1.57363	-0.42575	-1.2222	-1.33668	-1.74789	-0.61369	-2.49581	-2.24826	-3.26304	-3.36444
7	0.766401	0.360363	-0.90052	-2.9883	-1.74448	4.984527	8.747486	7.672101	3.962689	2.189309
8	-1.22035	-1.50605	-2.54188	-2.17218	-1.87382	-1.66508	-0.32145	1.441033	0.883534	1.984814
9	-3.96976	-5.83294	-4.81069	-1.85777	-2.20637	-2.7499	0.394319	0.616028	-1.61218	-1.92159
10	2.472252	4.416803	2.512953	0.729534	3.577607	2.923235	1.595245	-0.60482	-2.17139	-0.35259
11	-4.8882	-4.22298	-1.14958	-1.00566	-4.05692	-3.97153	-1.02556	-0.49116	-3.23198	-5.53235
12	0.718014	0.659087	-0.61054	-4.93416	-4.18202	-3.72061	-6.65855	-7.7086	-3.81197	-1.57769
13	-1.54135	-0.81454	-1.54073	4.376521	3.243036	2.718834	1.666538	1.493342	1.007323	0.769947
14	-1.23872	-2.83865	-0.42134	-4.82228	-6.99186	-4.88515	-4.98976	-8.78426	-6.80682	-0.46247
15	0.302771	2.100853	-2.10604	-3.5377	-0.05177	-3.38378	-6.10491	-3.57385	2.04159	1.807647
16	1.902477	-1.60498	-4.23237	-4.21334	-2.41157	-2.28414	-3.69704	-4.05958	-4.76771	-3.70876
17	0.005467	-1.04873	-0.68855	-5.18241	-12.705	-9.81602	0.668404	2.960547	-3.77326	-12.4181
18	3.414211	4.515652	0.863967	3.634251	-0.97217	-4.77011	-4.38996	-6.18959	-6.55031	-5.64339
19	0.71431	-3.84678	-8.80262	-13.1844	-10.395	-0.57816	-5.09172	-12.1581	-9.05344	-7.97242
20	-3.76895	-5.31599	-3.82498	-2.31223	-4.60525	-5.06135	-4.77687	-1.96122	-5.06978	-5.41854

Appendix C.22 20 participants' heart rate changes (bpm) on each second window when responding to the Fabric 4.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.338708	-4.0412	-4.58911	-5.1806	-6.30092	-4.61264	-6.19992	-6.90315	-6.31203	-4.87681
2	-0.53994	-2.52344	-0.29632	-0.564	-0.25125	3.149106	2.40763	1.37071	1.339372	-2.05787
3	-0.96237	-2.05051	-1.57766	0.929353	2.089451	-1.41516	-3.35191	-2.54643	-1.77004	-4.51214
4	-2.60097	-0.22896	1.045217	-0.21419	0.554037	3.062511	2.514501	1.632948	2.836636	2.123248
5	-1.86486	0.367107	1.31694	-0.65071	-2.02983	-2.91143	-5.41911	-4.20912	-2.42884	-3.62983
6	-1.05774	-0.82526	-2.836	-3.67349	-2.68924	-2.46574	-2.86085	-2.9721	-3.08597	-2.80845
7	2.289159	-0.53022	-1.28231	-0.50648	3.044885	4.736781	2.588398	-1.08118	-1.58866	1.273402
8	-0.30983	0.150181	1.705825	2.115332	1.598612	0.721167	1.087218	1.709878	-0.03975	0.708553
9	2.543858	-0.92625	-3.51152	-4.23389	-2.52181	-2.29011	-3.18267	-3.04334	-1.60049	-1.84538
10	-2.24616	-3.41874	-2.72106	-3.12976	-3.88065	-2.02164	-1.28811	-2.20285	-1.52808	1.10692
11	-0.10659	0.434669	1.770596	-1.59572	-4.07377	-2.91123	0.341862	0.323004	-2.39792	-2.9938
12	-5.37645	-4.56609	-0.16311	-0.38234	-3.68346	-4.47825	-2.24512	-3.93126	-5.74845	-4.48116
13	-0.03008	*	7.781291	7.218436	4.541683	*	3.655581	2.359715	0.297284	2.140059
14	-0.58953	-1.99115	2.744875	2.828853	-0.21194	-0.5737	0.904981	-1.93778	-3.26641	1.304504
15	3.667869	-0.57457	-0.79708	2.32132	0.176258	-2.42035	1.043982	2.497914	-1.69402	-1.18031
16	-1.89184	-2.13851	-1.00213	-0.84363	-1.83285	-3.31169	-3.47348	-3.03807	-2.90194	-2.96327
17	5.769374	*	-1.50936	-5.42778	-0.00211	*	3.329814	-7.8362	*	-7.95046
18	-0.13783	-0.47375	0.933708	1.837576	1.159592	-1.09413	2.483752	1.349219	-0.47375	0.883401
19	0.319699	0.681392	-3.6365	-3.47162	2.754888	0.014688	-4.70663	-2.38505	2.505124	-2.15345
20	-1.32662	-2.85651	-2.96595	-2.18445	-1.62613	-1.3616	-0.93755	-1.17857	-0.67774	0.529983

* Odd sample was excluded for the normal distribution of the data.

Appendix C.23 20 participants' differences of heart rate changes (bpm) in responses to the Fabric 3 and Fabric 4.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	1.170258	4.072755	4.063803	4.852018	4.916917	4.393955	6.557442	6.21981	8.163371	3.121887
2	-2.66631	3.657874	5.250229	3.893205	4.736186	1.810323	-2.97289	-6.10848	-3.83426	-1.1839
3	4.015713	3.605588	1.899247	1.003371	2.224884	4.086888	4.902036	5.228212	7.090726	10.67815
4	0.442424	-0.08938	-0.34124	0.801057	1.154561	-1.83745	-3.9078	-2.68187	-3.55941	-4.15605
5	6.326161	1.819605	-2.47444	-5.42815	-5.93686	-5.76912	-1.72863	0.902981	-2.79041	-3.53557
6	-0.51589	0.399511	1.6138	2.336803	0.941348	1.85205	0.365038	0.723842	-0.17708	-0.55599
7	-1.52276	0.890583	0.381793	-2.48182	-4.78936	0.247746	6.159088	8.753284	5.551349	0.915907
8	-0.91052	-1.65623	-4.2477	-4.28752	-3.47244	-2.38625	-1.40867	-0.26885	0.923289	1.276262
9	-6.51362	-4.90669	-1.29917	2.376115	0.315437	-0.45979	3.576992	3.65937	-0.01169	-0.07621
10	4.718411	7.835538	5.234015	3.859291	7.458254	4.944872	2.883353	1.598022	-0.64331	-1.45951
11	-4.7816	-4.65765	-2.92017	0.590064	0.016853	-1.0603	-1.36742	-0.81416	-0.83407	-2.53855
12	6.094462	5.225173	-0.44743	-4.55182	-0.49856	0.757644	-4.41343	-3.77734	1.936486	2.903469
13	-1.51127	-9.12404	-9.32202	-2.84192	-1.29865	-4.54887	-1.98904	-0.86637	0.710038	-1.37011
14	-0.6492	-0.8475	-3.16622	-7.65113	-6.77992	-4.31145	-5.89474	-6.84647	-3.54041	-1.76698
15	-3.3651	2.67542	-1.30896	-5.85902	-0.22803	-0.96344	-7.14889	-6.07176	3.735609	2.987962
16	3.79432	0.533527	-3.23024	-3.36972	-0.57872	1.027556	-0.22356	-1.02151	-1.86576	-0.74549
17	-5.76391	-6.44836	0.820806	0.245373	-12.7029	-18.4982	-2.66141	10.79675	7.508681	-4.46766
18	3.552036	4.989399	-0.06974	1.796676	-2.13176	-3.67598	-6.87371	-7.5388	-6.07656	-6.5268
19	0.394611	-4.52817	-5.16612	-9.71274	-13.1499	-0.59284	-0.38509	-9.77301	-11.5586	-5.81897
20	-2.44234	-2.45948	-0.85904	-0.12778	-2.97912	-3.69975	-3.83932	-0.78265	-4.39203	-5.94853

Appendix C.24 19 participants' self-reported rating scores to the Fabric 3 and Fabric 4 on the Valence, Arousal and Likert scales.

Participant	Rating Scores on Valence Scale to Fabric 3	Rating Scores on Valence Scale to Fabric 4	Difference of Rating Scores on Valence Scale	Rating Scores on Arousal Scale to Fabric 3	Rating Scores on Arousal Scale to Fabric 4	Difference of Rating Scores on Arousal Scale	Rating Scores on Likert Scale to Fabric 3	Rating Scores on Likert Scale to Fabric 4	Difference of Rating Scores on Likert Scale
1	-2	-2	0	-3	-2	-1	-1	-1	0
2	-2	0	-2	2	0	2	-2	0	-2
3	-2	1	-3	-2	-1	-1	-2	1	-3
4	1	0	1	-2	2	-4	2	0	2
5	-4	-4	0	0	0	0	-4	-4	0
6	0	1	-1	0	2	-2	-2	-3	1
7	1	1	0	0	1	-1	0	1	-1
8	-2	-3	1	1	1	0	-2	-3	1
9	1	-1	2	-1	-1	0	1	-1	2
10	0	2	-2	-2	1	-3	0	2	-2
11	0	0	0	0	1	-1	0	0	0
12	-2	2	-4	-2	2	-4	0	2	-2
13	-1	-1	0	0	-1	1	-1	-2	1
14	1	-2	3	-1	2	-3	1	-2	3
15	-3	-3	0	1	1	0	-2	-2	0
16	-2	-2	0	-4	-2	-2	-3	-2	-1
17	-2	1	-3	-3	-1	-2	-2	0	-2
18	0	-1	1	0	0	0	0	1	-1
19	-2	-2	0	-1	2	-3	0	-2	2

Appendix C.25 Differences of 20 participants' Delta power responding to the Fabric 5 and Fabric 6.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-12.1274	-3.51004	-7.06816	-5.97703	-6.8122	-10.1414	-3.21668	-1.10099	-4.3361	-3.31372	-7.64657	-16.3291	-9.6987
6.947513	3.858428	1.336501	-0.37599	-4.94909	4.676165	-2.99376	-2.49595	2.650699	-0.59695	-0.75817	4.335689	1.315349
5.747288	0.149632	-1.2004	0.285608	1.470248	-0.45963	1.585837	-1.80039	0.477859	4.326671	1.373152	1.41731	-1.96682
6.385315	8.193453	4.022539	9.836091	8.94979	-1.37485	10.31563	10.90514	9.627081	10.09982	5.331963	-0.97393	2.811245
-9.10698	0.5854	2.255025	-0.15197	-4.74859	-4.96947	-3.85752	1.798026	-2.9221	2.999694	2.686705	-12.7288	-1.43054
2.488349	1.093094	3.208233	2.0568	-1.86834	5.603132	0.562653	-1.97513	1.261829	-1.79694	-5.65963	-1.01111	4.635399
2.235729	-5.23002	-11.872	-1.52527	5.816945	-3.21521	-0.89713	-3.5013	2.551385	-0.00981	-2.30366	8.046709	-1.65073
4.570611	1.299217	3.251678	1.107427	1.444821	2.741637	9.781527	10.98363	9.462469	6.932989	2.680976	4.431234	2.507015
-17.9212	-5.5063	-7.51009	-8.06117	-11.0779	-6.64765	-1.40458	-7.77598	-4.2264	-5.38732	-2.17534	-6.45436	-4.43971
-2.70098	-1.38324	2.105519	-0.09979	2.6354	1.739099	-5.87556	-3.1615	-0.33013	-3.12339	-0.6928	-0.45115	-0.43988
-2.36106	5.584638	4.602138	5.994845	4.656264	6.070445	1.166766	4.818833	1.340312	2.697902	8.244432	-1.07312	8.193876
0.256723	-3.81981	-1.98414	-3.69693	-0.29694	0.576869	4.311777	-2.05025	-2.23597	-2.05517	3.955188	5.264463	-2.04933
22.02762	5.957281	7.083938	2.844887	0.308167	7.752406	1.851139	4.190414	1.954307	2.665215	0.792901	17.08272	3.729931
-6.03745	1.948147	-0.27591	-3.52405	-3.67156	-0.98173	-6.23745	-3.46578	-6.66604	-5.30211	-5.10321	-6.12566	-1.2158
13.01284	0.013661	-3.48712	-0.29679	-5.59952	-2.00234	1.113405	0.351399	-2.54717	-0.18307	-8.10591	4.747936	-3.79991
2.65884	2.535498	4.334427	4.494396	2.269064	5.332755	4.308709	2.907993	2.991481	4.301606	4.804784	13.26258	5.892232
-6.71881	-4.29645	0.077767	-0.93589	7.566095	1.268916	2.372922	1.257519	3.125761	1.071338	-0.81358	-0.29476	-2.35731
3.580491	4.073084	0.325894	-0.87167	10.54596	1.359134	1.24828	4.893367	0.315354	2.119877	7.471521	1.531055	-0.176
15.5043	5.272647	8.073819	4.252667	7.161677	6.04292	10.40497	6.732905	2.819581	6.917475	5.476217	7.517115	2.391963
0.093638	-6.6322	-4.11316	-1.04846	11.04697	1.491915	8.232839	6.424017	15.49817	-0.6425	4.749043	0.252555	0.724591

Appendix C.26 Differences of 20 participants' Theta power responding to the Fabric 5 and Fabric 6.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-18.3472	-3.26604	-2.43335	1.655289	-6.888	-1.50195	-6.60306	-1.93784	-5.59878	3.351685	0.858953	*	4.019054
0.911448	-0.9614	-4.51275	-1.3079	5.788369	-6.22487	0.862862	-1.08478	2.70869	2.855689	-1.22921	-0.3247	-4.70956
-4.08925	-5.42676	-5.92985	-6.34372	-1.69944	-6.36222	-2.35962	-3.31672	-1.06829	-3.77792	-4.94776	-1.33156	-7.98775
5.84133	1.803666	0.137616	2.226897	2.755235	-2.13742	4.43953	3.83473	2.770752	4.082684	2.105615	1.327928	-0.93121
-16.9015	-4.55736	-1.77125	-4.36557	-13.5524	0.518577	-4.93715	-2.90057	-5.82071	-6.22554	-6.028	*	-0.91945
-0.73811	-3.27015	-6.61632	-2.60786	0.169421	-0.26862	-2.40653	-1.59314	-0.96065	-0.63465	1.566454	-0.32706	3.086152
0.135616	4.351938	0.28923	3.057193	-0.38843	0.594754	2.006713	0.478477	-0.39188	0.347124	0.173412	1.18636	0.439818
-3.39014	9.482119	7.583541	4.666571	-1.25618	7.205845	0.320404	6.249738	0.121597	0.646567	0.503216	-4.00487	3.713834
-9.65934	-6.4289	-5.54333	-0.72691	-3.92271	-6.26073	-4.73602	-8.07714	-6.15298	-3.61959	-4.00486	-4.98287	-2.05244
0.282531	-4.16303	-7.54745	-2.17173	0.890039	-5.98526	-3.10919	-0.04245	-2.1748	0.932561	2.704907	-3.54254	-1.45465
-0.36585	-1.23201	5.104125	-0.26283	-8.84443	1.967948	-4.9948	-4.15585	-5.1391	-6.72427	-1.40167	-2.8454	1.690442
0.091821	-5.57483	-2.82784	-3.14979	-5.28178	-1.57645	-3.16625	-4.25699	-8.8708	-5.42665	-5.36487	-2.06088	-2.77348
7.385513	5.098008	7.981524	1.268178	1.990835	6.814638	-1.67897	1.136177	-0.66644	-0.57669	3.898087	4.753954	4.719274
6.409401	1.156089	-1.80029	0.981006	8.846033	-2.46631	4.133035	4.408639	9.212318	6.01849	8.974689	8.413338	2.378667
-1.31479	2.44559	2.565444	-0.35279	-2.92027	5.591128	-1.39905	0.91234	-6.22256	-5.04635	-0.3549	3.323953	1.388275
2.701679	1.436064	4.425864	-0.049	2.860008	1.96987	-0.7341	-0.54534	0.461735	2.43942	6.66724	7.374934	-0.77548
-1.78195	-7.44363	-3.26252	-1.6889	-1.00553	3.620444	-1.71515	-3.82374	-0.55651	0.215432	-1.12643	1.741843	0.655115
-4.76447	-9.69033	-4.65066	-7.87382	0.953059	-3.91522	-4.59291	-4.60622	-0.53757	-2.96817	0.044417	-1.62456	-2.2365
3.540668	4.675725	3.940239	2.630643	-0.04342	-0.2218	0.427638	1.454549	-0.45292	-2.62831	-4.64797	5.921406	-1.2105
9.38437	11.90965	12.92172	11.48313	4.18956	10.64537	9.386638	9.598084	*	7.230707	2.087685	4.87594	9.076479

* Odd sample was excluded for the normal distribution of the data.

Appendix C.27 Differences of 20 participants' Alpha power responding to the Fabric 5 and Fabric 6.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-4.27926	-6.47164	-6.05489	-5.15574	-5.06182	-2.46066	-5.61107	-6.66036	-4.40482	*	-4.28045	-7.16827	-2.18473
-4.41153	-6.05119	-5.87186	-4.15752	-6.5158	-7.34084	-6.30961	-5.83867	-9.05018	-5.37621	1.395734	-3.7995	-1.81743
-1.62344	-3.76299	-0.33674	-1.79226	0.63782	-1.28708	0.206683	-1.21876	-2.98666	1.654149	0.406563	-1.17721	-2.90842
4.503236	-1.10944	0.288971	0.204002	0.135925	-1.80572	0.054608	1.717531	-0.1139	-0.31668	1.278502	1.942519	2.081692
-1.30893	-0.94587	-4.11918	-1.13943	3.920309	-3.03407	3.684582	10.67613	3.472787	5.14113	0.519042	-2.46548	-1.41125
-4.09845	-1.71355	-1.77801	0.441777	-5.90276	-7.01244	-2.12738	-2.84673	-4.53899	-3.64999	-5.96361	-5.10185	-3.46259
-6.03061	-2.58024	-6.58123	-4.02828	-1.45725	-7.12544	-1.09612	-1.89683	-0.08797	-1.6666	-3.05019	-4.4744	-4.22271
-5.4299	0.874884	2.994989	-2.54548	-2.02514	2.049177	-7.26756	-4.67446	-6.70623	*	-6.19198	-3.9051	-0.96491
0.785103	2.359475	5.190852	-1.23611	-2.79585	4.639651	-1.03673	0.968386	0.121135	-0.75677	-1.21546	-3.95132	-2.07686
5.10144	5.47823	4.516415	3.966122	2.309064	3.038367	0.661942	2.189159	3.095942	1.179337	1.595623	2.963271	0.836928
1.784343	3.894582	2.544774	2.405091	3.523305	1.48223	6.768438	5.304405	6.305873	2.013786	1.007975	1.768541	3.692058
-0.53882	1.705822	-4.05947	0.691797	-3.49273	-1.37065	-2.04763	4.842198	0.01783	1.451156	1.837556	-1.98491	5.386447
0.617265	1.452291	-3.04927	0.014406	-1.26118	-5.93256	0.428855	2.227081	1.116603	3.352535	-3.00401	0.619977	-5.1174
2.299879	-1.07915	-8.02209	-1.27963	3.754088	-11.976	2.141661	1.524239	3.590353	2.30571	0.686373	3.66231	-5.60598
2.478523	2.103422	0.061998	1.559848	-0.62761	1.06677	1.225044	2.722193	-1.41721	0.957955	-1.81059	2.570163	-2.55801
2.738667	2.317861	-1.59483	5.069603	0.940129	-1.35823	1.183491	2.104162	1.053219	1.857695	3.622256	1.701234	5.478549
3.375633	3.602356	3.961608	3.02024	5.381235	3.103927	3.609908	3.105625	3.289573	1.635295	0.500611	5.10794	1.959271
-0.17402	5.998915	-2.04216	2.173438	4.105385	-2.8461	3.103537	4.837567	1.933414	3.007422	2.014681	-2.29782	2.082357
0.632371	-0.20647	0.312628	-3.45905	2.583189	2.907946	0.13526	3.092877	3.65157	3.995229	-3.67005	-0.82746	-2.87235
4.897131	0.18244	1.008315	-0.41486	-8.6177	0.653667	-1.28974	-0.65168	-3.82293	1.59908	-5.49345	1.704844	-2.89609

* Odd sample was excluded for the normal distribution of the data.

Appendix C.28 Differences of 20 participants' Beta power responding to the Fabric 5 and Fabric 6.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-2.11239	0.59641	-0.49498	1.614864	0.89764	0.120583	2.248223	0.966072	1.242225	1.33264	0.563043	0.425602	-0.01139
4.103332	-1.84467	-1.16424	-1.29579	2.901015	-2.12438	0.759244	-1.71287	2.100448	1.724155	-0.03644	3.06551	-0.37544
0.457638	-2.03688	-1.80871	-1.02283	0.620245	-1.08154	-1.53659	-1.59551	-1.63093	-1.1474	0.863976	0.388007	-0.8192
-0.90219	-1.0805	-0.841	-2.07154	-0.05784	-1.03536	-0.41576	-0.332	-0.09024	-1.4461	-2.0329	-2.46962	-2.6886
0.958754	0.381975	1.229	1.433084	-0.14141	2.854566	2.962707	-0.09163	2.488393	1.036891	1.288709	1.806906	1.733487
2.025716	-0.12067	2.69401	-0.47677	1.855108	*	-0.54431	-1.05283	1.385511	0.306504	-3.22021	1.354877	4.638059
-0.59372	-3.68751	-1.78419	-2.9695	0.684577	-0.9998	-0.62163	-3.04676	0.046148	-0.43423	0.098866	-1.89329	-4.0686
2.681027	0.658899	0.505987	0.984096	0.497407	0.387962	0.443701	0.578272	-1.24902	0.379961	0.763652	2.617141	0.291489
0.170302	0.219384	-0.65696	0.471044	-0.39688	-0.64876	1.885984	-0.63396	0.76041	-0.17308	0.380906	1.280204	-0.98667
-0.20496	3.835792	1.107243	2.715325	-1.42025	-1.01237	-0.39812	0.431101	-0.08438	1.295173	1.839095	2.099102	2.033046
3.030872	2.002958	0.233542	1.837692	0.065461	-0.7006	2.117969	2.694834	0.66106	1.453355	1.236368	0.253713	-1.039
3.125012	1.911297	0.401643	3.690334	-0.71317	1.305436	2.761623	4.118271	2.663204	4.252457	-0.05557	0.732503	-1.18695
0.590043	-1.23183	-0.37825	1.079857	0.554296	2.396834	-0.42344	-3.30218	-0.42801	-1.68919	-2.39318	1.631454	1.345839
1.212814	-1.22328	-2.55853	-1.66303	-2.04752	-0.49985	-1.59393	-1.50586	-0.63696	-0.63283	-0.50066	-0.56305	-0.78107
0.592139	-3.11066	-3.29184	-4.03534	-0.37443	-1.02924	-1.62438	-2.21263	-2.79079	-3.93727	-3.58358	-3.2609	-4.1652
1.291844	1.56473	-1.88503	1.08513	*	-1.56737	3.217835	2.269477	4.362703	3.8864	2.741951	1.847826	-0.3804
0.57589	1.02385	2.151437	3.46906	0.940757	3.215012	-0.6465	1.631606	1.410423	1.537902	1.062297	1.192183	4.73746
-0.55522	2.100568	1.848637	2.236442	0.273343	0.868764	-0.77432	1.217232	-1.04248	1.223366	0.013313	0.085797	1.584483
2.103699	3.14017	6.001335	2.135717	-2.02076	1.751558	-0.95988	1.10503	-1.47812	-0.18246	3.979358	1.573961	2.551289
-1.17469	3.280846	2.685198	3.525018	-1.32905	-1.83599	0.850646	2.927517	-0.82546	2.429388	-5.33144	-2.39669	-1.2636

* Odd sample was excluded for the normal distribution of the data.

Appendix C.29 Differences of 20 participants' Gamma power responding to the Fabric 5 and Fabric 6.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
0.396932	-1.32442	0.023302	-0.6601	0.246987	1.900126	-0.50884	-1.24481	0.50733	-0.20944	0.289402	0.041096	0.901353
1.806437	0.662961	1.744572	1.059243	3.76586	3.416627	2.863879	-0.27144	1.123023	1.48231	3.080775	3.155899	3.721953
0.104083	-2.15579	-0.99941	-1.34052	0.71063	-2.17342	-1.17889	-0.19605	-1.39961	-0.09724	-2.48093	-0.02883	-0.2314
-0.45202	0.058454	-0.62116	-0.69606	-0.18413	-1.34695	-0.61802	0.033232	-0.31632	0.130461	-0.41154	-0.82335	-0.65258
-3.98393	0.556498	1.141248	2.56743	1.930589	0.815779	-1.94483	0.10264	-1.14825	-0.91642	-0.31867	-2.23962	2.60572
-0.59481	-2.51544	-0.21529	-0.39944	-1.48621	-1.78166	-1.07197	-0.77618	-1.94537	-2.15086	-0.74496	0.875831	-3.42053
-2.01346	-0.26126	-0.86675	1.343941	0.968535	-0.13724	1.713512	2.230067	0.749323	1.155852	0.735087	2.306441	-0.29994
1.329126	0.420807	0.740398	0.768117	0.141908	1.642581	-0.17095	-1.36507	0.785233	1.095263	-1.19568	2.051595	1.165182
0.560216	-2.96741	-2.06445	-1.73816	2.087595	-2.29435	1.338416	-2.9862	-0.07843	-1.44747	0.107047	1.674648	-1.53463
-1.14775	-1.19818	-1.20607	-1.39465	-0.39844	-2.62968	-0.13346	0.441988	0.634641	-1.85705	-2.91105	-0.15393	-2.49844
0.26843	0.361548	-0.37968	-0.964	0.493386	-0.57957	-0.73824	1.593882	-0.38512	-0.35914	0.70936	1.478259	0.052314
1.08579	-0.32035	-0.18032	-0.74652	-0.14555	0.971961	2.351423	-0.13973	1.704975	-0.11278	-0.28038	1.208492	-0.13263
-0.43807	-1.00486	-2.27604	-1.57423	0.404445	-2.60254	2.318379	-0.1335	0.86144	-0.49577	-1.8824	3.38003	-2.42936
-2.02792	2.879448	2.027175	2.8694	2.083617	0.653437	1.805486	2.251783	0.937645	2.461458	2.064212	-0.54114	2.489582
0.352268	-1.76478	-1.05942	-1.80733	1.749003	-0.63702	0.086927	-0.45354	-0.09845	-0.3716	-0.7566	-1.05219	-0.22447
-2.35699	3.929681	2.720962	1.314865	1.078815	0.482122	-1.21542	1.764197	-0.10185	1.089697	1.685633	2.750721	0.948513
-1.10942	-0.12326	-1.68604	0.342806	1.169575	0.525725	2.025637	2.234107	1.532489	0.132494	1.576282	-0.91417	0.540705
0.771554	0.16236	2.230593	1.607602	1.816119	1.67381	-0.11152	-0.46538	0.332776	0.058613	0.995141	-0.40072	2.839203
3.268568	2.586797	0.520496	2.337038	2.025653	-0.90058	1.155966	1.739408	3.979229	3.639392	3.976393	2.814901	4.032887
-3.38174	0.500411	-0.84304	-0.34812	*	0.629098	-2.95364	-2.73075	-3.47835	-1.17422	-5.36746	-1.16864	-1.0551

* Odd sample was excluded for the normal distribution of the data.

Appendix C.30 20 participants' Frontal Alpha Asymmetry index to the Fabric 5.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
-0.6771	-1.63687	0.95977
0.36941	2.70229	-2.33288
5.12764	1.18475	3.94288
3.84775	6.49566	-2.64792
2.1088	-0.89198	3.00078
-1.01282	0.10041	-1.11323
-0.46631	-0.07265	-0.39367
1.4214	1.01311	0.40829
4.06682	0.86059	3.20623
2.21645	1.47762	0.73883
2.96433	1.04688	1.91744
3.83651	2.18677	1.64975
2.31249	1.6229	0.68959
3.97856	3.69871	0.27985
-0.39781	2.93078	-3.32859
2.98597	2.40643	0.57953
3.14328	2.81271	0.33057
4.23078	2.52911	1.70167
3.0667	1.6129	1.4538
3.76622	0.70229	3.06392

Appendix C.31 20 participants' Frontal Alpha Asymmetry index to the Fabric 6.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
3.03131	3.08183	-0.05052
4.65287	5.857	-1.20413
4.44578	1.07554	3.37023
2.77331	4.34264	-1.56933
1.13847	-1.35523	2.49369
1.53181	4.40901	-2.87721
2.29254	2.98004	-0.6875
7.75333	4.36926	3.38408
4.25356	2.69779	1.55577
-0.39264	-0.46895	0.0763
-1.7517	-0.88838	-0.86332
6.12943	5.35746	0.77197
0.54169	1.33961	-0.79791
2.26402	1.20254	1.06149
-2.76608	0.88753	-3.65361
2.19598	1.40843	0.78754
-1.56401	-3.36536	1.80135
2.32202	1.9654	0.35663
1.54322	1.05303	0.49019
1.51988	2.94173	-1.42185

Appendix C.32 20 participants' heart rate changes (bpm) on each second window when responding to the Fabric 5.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	2.690472	0.009842	2.04902	-0.61127	-2.30789	-3.45766	-3.9222	-2.82314	-3.22739	-1.90741
2	5.060576	7.440402	3.082515	6.854216	4.404464	3.926443	5.932152	1.831172	2.003705	-0.13668
3	1.876359	2.500807	0.19007	-1.08718	0.925828	3.047553	2.112608	1.140807	1.287283	2.554184
4	-2.05869	-0.21303	-2.51195	-4.65322	-3.90756	-0.9131	-0.49055	-0.11472	1.215219	0.074194
5	-4.27127	-5.67432	-4.00458	-0.65839	-0.4144	-2.0532	-4.43725	-5.98399	-4.2569	-3.38108
6	0.167488	0.395868	1.638454	1.603483	0.015868	-1.842	-1.94765	-1.82172	-2.83927	-3.8902
7	2.715277	3.599452	0.979844	-4.5385	-1.06907	1.77564	5.789133	*	7.74074	4.952424
8	-0.46939	-3.64377	-3.99767	-2.87242	-5.56656	-7.27683	-6.48785	-3.6613	-4.84745	-4.45462
9	1.627567	-0.93163	-3.18465	-2.7231	-1.27758	-3.58478	-5.98119	-3.44321	0.543313	-0.74869
10	3.751919	8.068809	7.662443	9.603213	9.726893	8.630039	6.804791	*	9.909782	7.83822
11	4.389892	-1.90034	-4.78739	-1.97362	4.223417	3.040469	0.601771	2.393772	7.830317	4.699467
12	-2.86915	1.192159	2.434444	2.059513	-0.36285	1.17802	1.932285	-3.90261	-5.94767	-2.847
13	1.067714	1.677657	0.412814	0.893385	-2.60338	5.30515	5.30515	0.243481	6.403819	11.15629
14	3.756268	0.56407	-1.62486	-2.34628	-6.86708	-10.8808	-8.58997	-5.33562	-6.40812	-6.0604
15	3.195189	2.798387	0.545642	3.735468	2.739121	-0.19441	0.377694	2.769064	-1.3606	-2.62219
16	*	1.662537	7.654549	6.195806	-1.26252	-3.08879	-4.10994	-5.1043	-6.32524	-6.14738
17	6.95926	9.995969	3.06565	-0.87666	-0.59515	2.941386	8.643874	*	2.444899	-5.06109
18	1.098646	-0.41596	-0.63872	0.205359	-0.77331	-1.45564	-0.35625	-0.11767	-1.64627	-1.32685
19	3.218395	0.248418	3.665014	9.59143	4.873092	5.260838	7.279488	1.65143	2.860352	4.492539
20	-4.84849	-5.32995	-3.14379	-2.77098	-2.76994	-1.49949	-0.78511	-1.72685	-5.03156	-5.26674

* Odd sample was excluded for the normal distribution of the data.

Appendix C.33 20 participants' heart rate changes (bpm) on each second window when responding to the Fabric 6.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	-1.48966	1.966992	-1.95961	-3.65925	-1.34081	-0.63385	-2.48412	-4.26177	-3.25273	-1.05217
2	4.051012	5.120616	*	*	6.483984	-1.54529	-0.39053	-4.31121	-3.44008	-0.83415
3	1.840548	0.233796	-2.01107	-2.32294	-1.11291	-1.60553	-3.23974	-3.04596	-0.83118	0.547619
4	-2.42925	-1.63221	-1.40443	1.595073	4.451781	3.766396	4.695472	3.737002	0.368066	-0.89025
5	1.315702	2.822223	2.451862	1.181589	-1.04492	-1.82473	0.947589	1.422026	0.516011	-1.3209
6	1.343596	1.001669	-1.89748	-3.11626	-3.52475	-4.20172	-4.70222	-4.70686	-4.18767	-4.05037
7	-2.48244	-2.51877	-1.68204	-3.28243	-1.76808	0.448052	5.277752	3.501546	0.518057	-3.51164
8	-1.62995	-0.60469	1.175226	-0.36173	-2.59786	-2.89343	-1.08145	-1.48847	-2.33689	-2.16863
9	1.301588	-1.80793	-2.70498	-1.996	-1.97992	-3.21455	-4.04335	-3.84261	-1.07358	-1.89597
10	0.53301	2.39448	5.33229	5.13903	1.561956	3.296156	4.326693	1.571114	2.297948	5.558627
11	4.123916	2.106755	-0.79885	0.439748	4.094536	3.298782	3.179722	1.079026	6.926839	6.343662
12	-3.89074	-6.85404	-7.43097	-5.14394	-5.82053	-4.2607	-2.57725	-1.90278	-2.27479	-4.70352
13	-1.20078	-2.3699	-2.88227	-0.78274	1.583739	0.186099	-0.04867	0.272974	4.109438	-5.32392
14	4.204923	0.198013	-0.44445	3.466078	4.288289	2.819505	4.785979	7.687064	1.268899	-3.01956
15	2.020857	0.887279	-1.9358	-2.98026	0.065303	-1.78587	-2.19921	-2.06842	2.390878	0.394377
16	1.012468	0.717272	-2.33064	-2.86359	-0.25368	4.364327	4.837162	2.508001	1.861226	3.969644
17	-8.32174	-8.22808	-6.0788	-4.56634	-5.78095	-6.01268	-4.44263	0.872908	-1.60882	-8.09523
18	-1.55299	-0.08099	-0.58344	-1.07697	-1.28084	-0.21877	1.44818	-0.15242	-0.43047	0.168457
19	-7.01353	-4.81951	1.674965	-1.25018	-2.48303	-2.8689	-6.43031	-6.06448	-4.95449	-6.46887
20	-2.01059	-2.29635	-1.19403	-4.50818	-7.13541	-8.77107	-8.79686	-7.30068	-6.93938	-8.28707

* Odd sample was excluded for the normal distribution of the data.

Appendix C.34 20 participants' differences of heart rate changes (bpm) in responses to the Fabric 5 and Fabric 6.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	4.180135	-1.95715	4.008632	3.047981	-0.96707	-2.82381	-1.43808	1.438628	0.025342	-0.85524
2	1.009565	2.319786	*	*	-2.07952	5.471729	6.322682	6.142382	5.443783	0.697467
3	0.035811	2.26701	2.201138	1.235763	2.038734	4.653084	5.352344	4.186769	2.118464	2.006565
4	0.370557	1.419179	-1.10753	-6.2483	-8.35934	-4.6795	-5.18603	-3.85173	0.847153	0.964444
5	-5.58697	-8.49654	-6.45644	-1.83997	0.630518	-0.22847	-5.38484	-7.40602	-4.77291	-2.06018
6	-1.17611	-0.6058	3.535931	4.719743	3.540622	2.359719	2.754576	2.885136	1.348396	0.160165
7	5.197716	6.118224	2.661888	-1.25608	0.699015	1.327588	0.51138	*	7.222683	8.464066
8	1.160554	-3.03909	-5.1729	-2.51069	-2.9687	-4.38339	-5.4064	-2.17283	-2.51056	-2.28599
9	0.325979	0.876299	-0.47967	-0.7271	0.702341	-0.37024	-1.93785	0.3994	1.616895	1.147284
10	3.218909	5.674329	2.330153	4.464183	8.164937	5.333882	2.478098	*	7.611834	2.279593
11	0.265976	-4.00709	-3.98853	-2.41337	0.128881	-0.25831	-2.57795	1.314746	0.903479	-1.6442
12	1.021592	8.046197	9.865418	7.203451	5.45768	5.438725	4.509537	-1.99983	-3.67288	1.856516
13	2.268496	4.047558	3.295081	1.676126	-4.18712	5.119051	5.353816	-0.02949	2.294381	16.4802
14	-0.44866	0.366057	-1.1804	-5.81236	-11.1554	-13.7003	-13.3759	-13.0227	-7.67702	-3.04084
15	1.174332	1.911109	2.481445	6.715732	2.673817	1.591456	2.576904	4.837482	-3.75148	-3.01657
16	*	0.945265	9.985193	9.0594	-1.00884	-7.45312	-8.94711	-7.61231	-8.18647	-10.117
17	15.281	18.22405	9.144454	3.689685	5.185801	8.954061	13.08651	*	4.053721	3.034135
18	2.651631	-0.33497	-0.05528	1.282333	0.50753	-1.23686	-1.80443	0.034742	-1.2158	-1.49531
19	10.23193	5.067923	1.990049	10.84161	7.356126	8.129738	13.7098	7.715908	7.814847	10.96141
20	-2.8379	-3.0336	-1.94976	1.737196	4.365475	7.271584	8.011751	5.573834	1.907814	3.020329

* Odd sample was excluded for the normal distribution of the data.

Appendix C.35 19 participants' self-reported rating scores to the Fabric 5 and Fabric 6 on the Valence, Arousal and Likert scales.

Participant	Rating Scores on Valence Scale to Fabric 5	Rating Scores on Valence Scale to Fabric 6	Difference of Rating Scores on Valence Scale	Rating Scores on Arousal Scale to Fabric 5	Rating Scores on Arousal Scale to Fabric 6	Difference of Rating Scores on Arousal Scale	Rating Scores on Likert Scale to Fabric 5	Rating Scores on Likert Scale to Fabric 6	Difference of Rating Scores on Likert Scale
1	2	1	1	2	2	0	2	1	1
2	2	2	0	-2	-2	0	3	3	0
3	-2	3	-5	-2	3	-5	-1	3	-4
4	4	3	1	-1	3	-4	4	3	1
5	-4	1	-5	0	0	0	-3	2	-5
6	1	4	-3	0	3	-3	3	4	-1
7	1	2	-1	1	2	-1	2	2	0
8	-1	1	-2	0	3	-3	0	2	-2
9	1	1	0	0	1	-1	0	1	-1
10	2	1	1	4	0	4	2	0	2
11	1	-1	2	1	-1	2	1	-1	2
12	-2	-1	-1	0	-1	1	-2	-1	-1
13	2	2	0	0	0	0	1	2	-1
14	2	3	-1	2	3	-1	2	3	-1
15	0	2	-2	-1	0	-1	1	1	0
16	2	4	-2	0	4	-4	3	4	-1
17	1	1	0	-1	-1	0	1	0	1
18	0	1	-1	0	1	-1	0	1	-1
19	0	0	0	2	3	-1	1	2	-1

Appendix C.36 Differences of 20 participants' Delta power responding to the Fabric 7 and Fabric 8.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
1.591288	-4.50007	-6.13567	-5.21808	0.990898	-6.50685	3.119672	-1.08429	3.07489	-2.56135	-1.0042	-6.75472	-8.72786
12.93575	1.041657	0.838725	3.604479	12.2508	5.699725	-1.90097	-2.47732	7.064545	3.028079	-0.77725	14.75664	-2.00464
-12.745	0.678458	2.003879	4.416053	-0.40169	0.141121	-7.95922	-7.52905	0.587699	-3.28617	1.357919	-10.5273	1.481263
7.188265	-3.3576	-5.3958	-3.06718	2.253929	-4.37325	5.00077	3.288335	5.542441	1.563932	2.895091	3.925041	-6.32084
-0.41086	-0.15869	-0.53296	-2.35825	-2.28669	0.889807	-0.78517	-3.04533	-2.10417	-6.0586	-3.22347	3.052739	-1.05286
2.106888	4.079547	6.658068	3.787351	3.167241	4.055264	-0.98394	-0.28659	0.430761	1.146289	3.413342	2.617033	1.510178
-19.945	-8.77523	-17.5844	-5.05263	-12.2063	-16.9944	-8.58482	1.663631	-3.49344	2.829836	7.479223	-18.0168	-8.95715
-18.8554	0.737522	-0.24568	2.134601	-10.352	2.366471	-7.22675	-7.23011	-10.1209	-0.50878	-5.04638	-21.2938	5.142661
2.842847	0.416451	4.768924	1.776329	-5.71865	3.710783	0.746077	-1.66601	-3.64091	-0.88099	-5.89648	-10.6967	0.917393
-8.51975	-1.90495	-2.59395	-2.96927	-2.86645	0.163496	-10.6291	-8.3191	-10.5095	-4.86685	-2.44517	-4.08516	-2.56542
10.48369	-2.28977	2.260943	5.106803	2.440934	-1.38685	6.515894	5.093227	5.437255	5.436874	2.84555	3.055666	5.857937
-4.67233	-9.47897	-8.59059	-8.79822	-2.05387	-0.86227	-10.6097	-10.1243	-4.55558	-7.85343	0.013356	1.112909	-8.26335
-9.08934	-0.67955	-3.6359	-2.18331	-10.6019	-1.67141	-7.59305	-5.39613	-4.01831	-5.2809	-6.37402	-14.2272	-3.61864
-5.78174	-1.9697	-1.73673	-3.3058	0.997803	-3.17592	-1.91865	-1.84662	-0.91976	-0.18326	-0.57019	-4.67969	-4.16502
-0.3747	-3.53227	-7.66445	-2.30647	1.925516	-9.25743	1.266148	4.097124	2.3696	3.175145	2.251308	1.826547	-2.57262
-2.92822	-6.12247	-11.8062	-4.61037	-3.61231	-13.3154	-6.4438	-5.28149	-4.86454	-6.03364	-4.46613	1.284351	-4.93331
-4.34637	8.72619	3.605676	13.42788	5.195844	1.203609	8.602516	3.456327	11.38789	7.284846	9.88893	7.077509	11.88283
3.326077	-1.99557	-6.76749	-2.66623	-0.38498	-7.203	2.372713	-2.17293	2.131848	1.109446	4.120003	2.720582	-2.8228
-7.65959	6.202559	8.815997	3.208823	1.488895	4.751791	7.567654	6.600694	-1.49416	2.572216	-0.07299	-1.83755	4.875288
-5.37841	3.649144	3.337257	1.973849	-0.52424	1.005841	-6.86385	-1.21961	-5.49729	-0.8053	5.253953	-5.60991	3.956928

Appendix C.37 Differences of 20 participants' Theta power responding to the Fabric 7 and Fabric 8.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-9.45953	3.885313	2.878574	2.770846	-0.44698	4.795234	-3.27341	-0.65406	2.298533	-0.1668	-3.3938	-8.59968	2.395681
1.320359	-6.92871	-7.63762	-6.96834	-0.26474	-8.09715	-4.27651	-4.29712	-1.99342	-3.74902	-5.4342	0.510837	-9.90126
-11.0985	4.502815	2.537333	5.378304	-1.60651	-3.26957	-5.24467	1.534278	-0.36652	0.44228	-1.02441	-9.90448	0.803562
2.358007	12.48986	11.17972	9.340065	-2.27316	9.184298	6.003641	6.299068	3.159168	5.739341	0.707543	2.316976	9.430201
5.467086	11.42998	5.998047	10.71467	2.716319	3.923756	8.161669	*	3.665009	7.118737	1.046585	4.357371	5.42907
-5.2364	1.237535	1.643095	0.145841	-8.73673	1.72585	-6.9318	-4.23462	-6.95967	-6.90169	-9.12785	-12.2862	-3.71437
-5.66104	0.860295	2.553685	-0.68611	5.904408	-3.8842	3.066878	2.907954	5.898123	5.565574	3.148471	-5.06188	0.72739
-13.3647	2.66461	2.38057	4.990857	-7.55953	1.078679	-3.48505	-2.23366	-2.00533	-3.30214	0.829682	-14.1494	4.841407
0.211582	6.592743	9.542072	8.195187	0.70485	4.302059	2.028382	8.030323	4.772158	5.268147	4.064303	-9.28984	5.916291
1.859259	6.189664	1.888164	6.043235	1.858703	3.78275	1.380023	3.164114	2.556985	-1.27856	-2.33733	4.579531	5.098187
5.240462	-1.23447	0.182915	-2.53651	-0.29645	-0.67196	3.450468	1.765687	3.476416	2.115331	2.777277	2.337315	-1.91411
-2.67429	-3.19877	-6.74807	-5.10026	-2.47854	-7.79143	1.30649	0.573625	-4.15547	-8.50915	-5.11766	-0.05136	-7.48035
-7.11457	-3.96653	-2.22647	-5.69149	-4.82175	-0.52159	-6.11833	-4.79019	-3.8842	-5.08319	-4.35139	-4.72096	-4.15477
-4.05416	-5.89164	-6.24342	-5.48742	0.995933	-3.91632	-2.96002	-2.78101	-0.83913	-3.43928	-2.83897	-0.27474	-6.41454
2.336496	1.52083	0.284667	1.122298	3.412012	4.540835	-1.35313	-2.34935	0.033744	-3.53526	2.719023	0.791654	-0.59165
-3.72352	-3.39428	2.244768	-6.50542	-5.55226	5.294739	-2.32487	-5.10315	-3.32879	-5.4667	-10.3872	-6.7412	-2.35348
5.155346	2.900218	2.351271	1.387258	6.347436	1.730406	0.737163	0.595354	1.492034	1.433346	2.674812	5.546023	2.563345
0.064967	1.031823	-0.50397	5.117253	2.369514	-1.09643	-1.39324	0.997214	6.04876	5.195043	4.037318	4.359065	0.919967
-4.90092	-2.13617	2.21612	0.148014	4.885042	1.831406	-1.42644	-2.5317	-0.43114	-1.83254	-0.4579	-1.37931	7.62723
-0.39152	0.142458	-4.49368	0.99439	0.487084	-6.79345	4.180935	2.45085	4.208006	1.12773	-2.1553	0.339329	-0.17285

* Odd sample was excluded for the normal distribution of the data.

Appendix C.38 Differences of 20 participants' Alpha power responding to the Fabric 7 and Fabric 8.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-2.68199	4.130663	2.825744	-1.10311	-3.63821	-2.02048	-1.41087	0.374436	-1.94509	0.194569	-5.98494	-3.91124	-6.99413
*	-3.34988	1.460682	-5.25468	-6.5234	-3.63654	-11.9645	*	-10.4551	-7.38057	-5.45758	-9.02494	-5.09263
-2.29886	1.942335	3.734363	1.286878	-1.77995	5.141605	1.525202	2.883581	1.887623	2.151795	0.551092	-2.63445	3.163343
0.32782	8.822973	6.122951	8.635759	4.214441	0.02247	4.051007	6.66871	3.657979	7.486391	5.923019	-4.60534	4.315798
-3.61208	-2.44714	-2.52015	-3.96141	-1.59807	-5.54019	-5.68691	-1.14214	-1.65448	-4.88138	2.004151	-1.8944	2.287772
-1.46537	0.192025	0.315756	1.469566	0.88427	3.153016	1.390884	1.877124	3.531557	1.784507	-0.41842	-1.95612	-2.2622
-6.74835	0.722952	-3.58776	-0.8777	-0.17291	-1.61108	-4.6872	-3.43535	-2.70331	-2.93332	-3.42851	-2.14443	-3.68621
-1.2357	0.929199	2.685483	2.563113	-1.48403	3.571744	-0.50299	-1.45636	-3.25771	-2.09196	-3.79778	-3.29806	2.881424
3.294052	5.182604	5.238866	2.252167	-0.78073	6.955099	2.305677	5.437764	2.198562	2.777456	2.993303	-5.79348	2.230345
-2.73343	1.166051	4.595771	2.469593	-0.30281	5.427103	-1.43781	-0.60988	-1.11195	-0.73603	3.621642	1.126731	2.485966
2.20421	-0.20999	2.830478	-0.80541	-0.39152	2.544822	0.741604	-0.33439	2.060313	0.370205	-0.14466	3.876124	-0.01591
-0.10917	-1.11505	-3.09166	1.102258	4.606351	-1.26909	-1.38392	-2.60172	0.990463	-1.48887	1.649782	5.825683	0.954475
1.45738	3.16893	5.798884	4.505114	4.242531	7.757148	7.768268	3.5576	7.647476	4.20624	0.379817	3.525347	7.130165
0.021325	-2.90295	-1.21515	-0.1606	-1.44458	-0.06352	-1.20834	-1.24387	-1.34234	-0.7599	-1.38003	-0.67377	-1.78949
-2.00215	1.316711	2.014094	6.181331	-3.29614	1.632233	-4.27195	3.80368	-4.62468	-1.53765	1.729425	4.595371	2.72574
-6.28174	-4.64925	-4.05844	-8.38322	-4.75586	-4.75619	-4.08348	-2.64986	-6.2741	-6.05495	-1.1929	-6.08997	-6.38417
-0.11285	-5.56928	-3.39523	-3.8342	-2.91877	-2.40464	-0.55415	-6.73469	-2.96415	-4.16058	-4.66251	0.970148	-3.42879
0.198514	0.886374	1.785115	3.047965	-0.68998	-3.77033	-0.41942	-0.32204	-4.37684	-3.25693	3.997993	6.436285	3.380456
-1.28182	-4.394	-2.16755	-4.24891	-6.3399	-6.51596	2.643962	-0.4652	-3.44401	-0.98828	-3.56604	-1.75982	0.826901
-1.73863	-1.0218	-4.61815	-3.41201	0.037873	-6.31225	2.334807	0.968968	-2.19868	-2.664	-2.75093	-4.45476	-3.28244

* Odd sample was excluded for the normal distribution of the data.

Appendix C.39 Differences of 20 participants' Beta power responding to the Fabric 7 and Fabric 8.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-4.91201	0.142008	-0.50152	0.287811	-1.97365	-1.30995	-1.89161	-1.65675	-1.93737	0.114315	-0.40157	*	-0.21871
-4.07219	-3.43672	-2.09929	-2.56266	-1.21543	-0.93949	-1.93367	-3.20636	-1.92634	-3.07771	-0.82119	*	-0.47681
0.747119	0.639319	0.876344	-0.00904	0.596972	*	-1.65269	-1.29769	-1.05209	-0.26704	-1.23655	-4.7E-05	-0.85095
0.034547	2.160184	1.347773	*	0.509923	*	*	4.123289	2.821957	3.124849	0.751837	1.560945	*
1.026244	0.002399	-0.46746	-0.17126	-0.66614	-0.25898	0.895347	2.718001	2.189946	3.30114	1.848943	0.233376	1.338495
0.465467	0.351316	1.437555	1.108714	2.661454	-1.37844	-0.45151	-0.81323	0.103049	0.006837	1.243309	0.815333	0.923577
-1.73441	-0.17266	-1.32745	-0.34842	1.064284	-1.20797	-1.96819	-3.04812	-0.86812	1.014783	2.340633	0.123202	0.367889
-1.94646	-0.63818	-0.25005	-1.66809	-2.13628	-1.87206	-1.57332	0.242067	-2.69506	-2.20931	0.976684	0.184688	-1.34342
-0.82098	2.21567	0.753072	2.711879	4.785379	0.431047	*	2.708003	3.131272	2.534652	2.743868	0.22866	3.534196
-4.31065	0.741231	-1.20938	1.468807	4.497753	-1.00795	-1.23005	0.676962	2.5169	2.957184	*	-0.21445	0.335195
-1.09422	0.526601	0.232714	0.078721	-1.65007	-0.81717	-1.28637	0.734664	-2.57792	-1.15729	-2.64754	0.064727	-0.4098
1.09294	-2.37525	0.496464	-0.8757	-4.73381	-0.58083	-0.97832	-0.49909	-2.9213	-1.85025	-1.96708	-0.87758	-2.14504
-0.63409	2.036636	2.240749	0.119436	0.2161	0.326621	-0.79624	0.647654	-0.54119	-1.29184	-1.23342	2.42411	-0.20482
-0.79085	-0.29884	-0.78549	-1.62575	-0.65026	-1.63803	-2.4702	-1.19941	-1.50352	-1.82742	-1.61644	0.120513	-0.94225
-0.7326	-2.47415	-4.55191	-2.52208	3.514217	-1.9852	-0.94014	-1.52507	0.151905	0.758895	-0.1092	-0.49001	-2.42755
-1.22595	-2.07667	-1.00425	-0.90849	-1.18572	-2.59301	-0.13091	-1.00257	-0.20349	-0.05245	-0.53799	-0.10779	-0.49442
-0.50276	-1.5255	-1.44361	-0.99236	-2.35038	-0.51486	0.324176	-0.17354	0.79833	0.070919	-2.13283	-0.11291	0.843017
-2.10451	1.774551	-0.08442	-0.04665	-0.82572	-1.14301	-2.11503	0.286191	-0.65613	-0.03245	-0.43969	2.215611	-0.80079
0.973746	1.035535	-0.83592	0.84393	3.224161	-3.1998	*	4.976402	1.394073	2.223549	*	*	1.693009
1.51814	0.904924	-1.42143	1.984346	-1.92258	-0.76528	-1.19473	2.487759	-0.87608	1.638066	0.277342	2.591494	-0.07822

* Odd sample was excluded for the normal distribution of the data.

Appendix C.40 Differences of 20 participants' Gamma power responding to the Fabric 7 and Fabric 8.

Fp2	P4	O2	Pz	F3	O1	F4	C4	Fz	Cz	C3	Fp1	P3
-1.00172	-1.75836	-0.99011	-0.26088	0.496672	-2.09619	-0.95405	-0.96976	-1.27021	-1.11844	-1.10861	-0.05001	-1.20994
1.331608	2.229923	1.119433	1.046548	-1.39439	0.753985	1.432118	1.305549	1.653456	1.230841	-0.96495	0.640278	-0.17113
-2.08411	-3.06657	-3.06678	-2.14649	-1.66758	-3.36637	-1.97283	-3.58637	-1.24578	-1.48311	-1.61572	-0.31339	-2.67506
0.178207	0.611166	1.064725	-0.13916	-1.40339	-0.15779	0.05971	0.225004	-0.05301	-0.34785	-1.13504	-1.69941	0.344827
-0.5867	-2.44476	-1.48596	-4.01724	-2.57829	-0.77855	-1.18588	-0.8057	-2.10969	-0.95724	-2.61281	1.412921	-2.82791
0.418567	3.227818	3.06019	1.793313	2.815368	1.099234	1.307179	3.990372	3.166235	1.207311	0.713829	-0.00489	0.557137
1.202408	-2.16518	-2.45711	-1.68513	-0.07918	-2.77202	-1.23706	-0.56523	-0.90809	0.529835	0.100193	2.28747	-3.5052
-2.07925	0.282263	-1.27133	-1.151	-1.74416	-0.69701	-1.24025	-0.41728	-1.4644	-1.12164	0.008975	1.45637	-0.66993
0.246958	0.426994	0.273452	1.121514	1.11686	-0.45051	3.445261	1.900767	2.420233	1.806943	3.025722	3.933321	1.162253
4.02509	1.737894	1.569211	2.699854	1.127097	1.91734	0.613526	1.611602	1.03203	0.889489	4.842242	3.636495	0.797885
0.829566	0.650929	-1.18036	0.988326	0.787872	1.148297	-0.15915	0.574067	-0.02933	0.962382	-0.86931	1.445215	1.588897
0.08501	-0.17842	0.192496	0.427908	-2.03652	0.540716	-0.90547	-1.19652	0.208519	0.327155	0.05407	-0.43479	1.726146
0.302406	-0.66072	-1.67592	-1.07446	0.101333	-2.1438	2.067555	0.979765	-1.73746	-0.69752	1.204092	0.990152	-0.62851
-1.45061	-2.5012	-3.885	-3.49602	-3.14865	-3.55891	-2.36039	-2.13862	-2.73691	-2.86466	-3.21042	-0.90024	-3.86399
0.429441	2.189202	1.834612	1.974195	2.752175	2.446817	0.846112	2.465999	1.755761	1.605092	0.864307	1.852065	-0.35218
-0.05794	-0.32249	-0.17379	-0.60014	1.242469	-1.02197	1.552198	-0.64615	1.285876	1.040293	0.400049	1.652051	-2.09296
1.116414	-1.48215	0.199484	-0.7513	-0.46426	2.894309	-2.70735	-0.81117	-1.53826	-0.76063	0.945718	1.492532	3.746984
0.502719	0.353945	1.102545	0.673784	1.269146	1.726914	1.435194	1.145386	0.512113	0.382283	0.405828	-0.70612	1.086969
2.248105	3.000636	-4.62411	3.074193	6.123557	-3.31776	4.44533	*	*	*	*	2.90513	1.695361
-1.52481	0.690757	1.846792	0.090865	-2.60874	1.564796	1.863465	1.350347	-0.25177	2.05039	1.92282	-2.81422	2.342977

* Odd sample was excluded for the normal distribution of the data.

Appendix C.41 20 participants' Frontal Alpha Asymmetry index to the Fabric 7.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
0.36273	-1.54283	1.90556
-7.72654	-5.87489	-1.85165
1.80788	-0.95711	2.76499
3.90646	3.38466	0.5218
-3.14109	0.76069	-3.90178
2.30597	2.17597	0.13
-3.16849	0.0859	-3.25439
1.06316	-1.31333	2.37649
-0.45467	-2.98771	2.53305
0.21612	2.82915	-2.61303
0.89615	1.21829	-0.32214
3.48398	5.04187	-1.5579
0.5145	0.82369	-0.30919
0.8858	1.15625	-0.27046
0.25725	0.65383	-0.39658
-0.28127	-4.05189	3.77062
1.88965	0.78784	1.10181
2.49636	2.14394	0.35242
2.64386	4.24112	-1.59727
-2.17329	-0.98522	-1.18807

Appendix C.42 20 participants' Frontal Alpha Asymmetry index to the Fabric 8.

Frontal Alpha Asymmetry Index = Alpha Power (F8 +Fp2 + F4) / 3 – Alpha Power (F7 + Fp1 + F3) /3

Alpha Power (F8 +Fp2 + F4) / 3	Alpha Power (F7 + Fp1 + F3) /3	Frontal Alpha Asymmetry Index
2.32791	3.81651	-1.4886
3.66203	-0.07824	3.74026
1.89495	1.45161	0.44334
1.79531	2.97007	-1.17476
2.37107	1.05526	1.31581
3.98685	2.44228	1.54457
3.28978	1.97742	1.31236
1.70915	1.8605	-0.15135
-3.95643	-0.42625	-3.53018
2.66085	3.12563	-0.46478
-1.12615	-0.02723	-1.09892
5.25324	1.13818	4.11506
-3.24626	-3.74924	0.50298
1.56564	2.87131	-1.30567
2.67113	-0.60001	3.27114
3.68028	1.6236	2.05668
2.93363	2.45362	0.48001
3.18367	-0.59399	3.77767
2.9069	6.41841	-3.51151
-2.64337	0.63432	-3.27769

Appendix C.43 20 participants' heart rate changes (bpm) on each second window when responding to the Fabric 7.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	-0.55197	1.807029	-1.70681	-2.98046	1.607836	-1.59716	-1.83335	-1.35867	-3.01867	-5.03244
2	2.547444	0.090776	-0.56526	-6.30229	-6.71972	-2.91409	-3.26755	-2.35247	0.84939	1.161481
3	1.055092	-0.34814	-2.54398	-2.21158	-1.05705	1.505476	0.298368	-0.00309	-0.46313	1.686437
4	1.977385	3.347254	2.383286	2.951453	4.977016	4.636895	2.720209	2.551713	2.883992	0.389154
5	-6.19409	-4.99897	-6.15441	-4.24093	-0.60259	-0.31439	0.385796	0.031938	1.072749	-1.13675
6	-0.62777	-0.36773	-1.80392	-2.69279	-2.38106	-1.66374	-2.56954	-1.38799	0.035545	-0.63147
7	0.375063	-3.52414	-6.71692	-8.2404	-6.56256	-6.35476	-4.9838	-8.08264	-8.06758	-8.11455
8	-0.18208	-1.6759	-2.58569	-1.59218	-2.2848	-3.88224	-4.65876	-3.83985	-1.62694	-1.53079
9	-2.56152	-2.10271	-1.50088	-2.9153	-4.15155	-3.45056	-1.73061	-2.20416	-1.89666	0.0568
10	-2.08697	-0.00244	-1.25621	-4.99238	-4.0074	-0.60439	-0.5771	-2.03528	-1.36228	0.018905
11	-5.75644	-6.84814	-7.21679	-2.61107	-8.57358	-12.374	-7.89635	-4.87945	-8.38213	-10.1146
12	-0.75323	0.16147	-1.27953	-1.79199	0.015108	1.210312	2.41451	2.673003	1.964911	-3.94116
13	1.763915	0.574418	1.64707	-0.46672	-0.33678	-0.47884	2.059396	1.101992	0.809395	0.123566
14	4.001517	2.408262	1.985978	3.514821	1.466076	1.99279	5.160654	9.839372	6.775855	2.970285
15	-0.52335	2.156535	-0.70309	-1.08323	-3.5163	-0.95591	-0.67072	-2.87731	-4.84245	-5.53857
16	-0.04045	-4.78215	-5.50252	-3.28812	-5.50673	-7.84998	-9.36336	-8.14169	-6.89448	-0.34319
17	-7.23417	*	*	-8.48047	-4.6472	-5.94367	-8.55867	-8.15791	-3.88228	-5.39665
18	2.63042	3.022577	1.544773	-0.7678	-1.02582	-4.70861	-4.24184	-3.19393	-2.15798	-4.73804
19	3.194737	2.452714	3.038693	-10.1369	-12.4988	-5.60946	-9.1896	-5.02291	-1.53711	-6.29047
20	0.458542	1.567613	-1.27999	-6.30589	-5.87363	-4.61254	-4.11348	-6.91188	-8.71666	-9.52264

* Odd sample was excluded for the normal distribution of the data.

Appendix C.44 20 participants' heart rate changes (bpm) on each second window when responding to the Fabric 8.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	-0.59227	-1.79879	-1.28924	-0.94939	-1.53387	-0.26974	-2.97358	-2.06036	-3.11344	-3.43034
2	-0.04641	-1.66288	0.200906	-2.9962	-2.42623	0.612101	-1.26325	2.239327	6.184518	6.344427
3	-1.28089	-1.21762	0.706503	-0.59021	-1.73966	-1.41473	0.102026	-0.31723	-3.0081	-3.40664
4	-5.60827	-8.71614	-7.862	-4.23268	-3.03583	-3.1519	-3.23325	-1.88279	-0.69687	-1.81427
5	0.027512	-5.18971	-5.33077	-6.10678	-5.3134	-2.50222	-1.89304	-3.97954	-5.48721	-4.62778
6	0.085985	-0.37576	0.198282	-0.58909	-1.38279	-1.67324	-2.23831	-2.36183	-1.78322	-1.67324
7	-0.88727	1.067709	3.802622	1.833999	0.672259	2.461535	2.658228	5.657429	*	8.086136
8	0.097761	-0.78777	-1.34467	-1.41611	-1.72367	-3.02274	-0.43354	-0.97718	0.08791	2.668135
9	-1.46245	-0.26596	-1.8559	-4.40212	-3.61136	-1.37935	-1.76927	-3.71074	-3.26754	-2.27856
10	0.737932	0.345775	1.582024	1.950342	0.693177	0.784444	3.603204	2.995484	3.327608	4.523429
11	-4.90482	-6.82659	-5.46476	-3.78348	-10.6749	-10.8874	-6.77946	-3.23116	-3.97029	-6.11387
12	*	-4.14837	0.269517	-1.91169	-7.58055	-7.46677	-3.48186	-6.65809	-7.85149	-6.14272
13	-1.06833	3.904811	8.241785	2.835919	2.695498	5.566677	2.896837	2.061133	1.176751	3.252278
14	0.06151	5.033265	1.068945	-0.77181	5.831547	9.319278	2.53104	-1.65303	0.186617	-2.45977
15	-4.33747	0.145513	-1.03036	-5.20407	-2.76816	0.919249	-2.36892	-5.13739	-1.98442	-1.60231
16	1.08652	-0.93637	-3.20131	-1.40854	5.010067	4.355096	-0.54923	-1.36696	-0.70358	1.575016
17	-3.46784	-2.61015	1.639224	-3.86624	-5.63155	-2.78843	2.618977	0.607691	-4.14814	-8.79335
18	1.435058	-0.13864	0.38297	1.264765	0.144061	-0.93564	-0.32966	-0.35276	-2.0199	-2.53633
19	-1.58806	3.356238	2.840846	6.018559	8.495555	1.802926	0.676331	1.697096	-4.5313	-4.07825
20	-2.06438	-3.23207	-2.87001	-1.85931	-4.51951	-7.79158	-6.01637	-2.42721	-1.7878	-2.29798

* Odd sample was excluded for the normal distribution of the data.

Appendix C.45 20 participants' differences of heart rate changes (bpm) in responses to the Fabric 7 and Fabric 8.

Time Window / Participants	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.040295	3.605824	-0.41756	-2.03106	3.141708	-1.32741	1.140235	0.701696	0.094772	-1.6021
2	2.593858	1.753659	-0.76617	-3.30609	-4.29349	-3.52619	-2.0043	-4.59179	-5.33513	-5.18295
3	2.335977	0.869482	-3.25048	-1.62137	0.682613	2.920211	0.196342	0.314133	2.544969	5.093073
4	7.585651	12.0634	10.24529	7.184132	8.012851	7.788794	5.953454	4.434508	3.58086	2.203427
5	-6.2216	0.190741	-0.82364	1.865853	4.710815	2.187834	2.278832	4.011473	6.559954	3.491031
6	-0.71376	0.008026	-2.0022	-2.1037	-0.99827	0.009501	-0.33123	0.973843	1.818763	1.04177
7	1.262334	-4.59185	-10.5195	-10.0744	-7.23482	-8.8163	-7.64203	-13.7401	-17.8988	-16.2007
8	-0.27985	-0.88813	-1.24102	-0.17607	-0.56113	-0.8595	-4.22522	-2.86267	-1.71485	-4.19893
9	-1.09907	-1.83675	0.35502	1.486821	-0.54019	-2.07121	0.038661	1.506572	1.370874	2.335356
10	-2.8249	-0.34822	-2.83824	-6.94273	-4.70058	-1.38883	-4.1803	-5.03076	-4.68989	-4.50452
11	-0.85162	-0.02155	-1.75203	1.172414	2.101299	-1.48662	-1.11689	-1.64829	-4.41183	-4.00077
12	6.419351	4.309845	-1.54905	0.119691	7.595657	8.677086	5.896369	9.33109	9.8164	2.201557
13	2.832247	-3.33039	-6.59472	-3.30264	-3.03228	-6.04551	-0.83744	-0.95914	-0.36736	-3.12871
14	3.940008	-2.625	0.917033	4.286634	-4.36547	-7.32649	2.629614	11.4924	6.589238	5.430054
15	3.814119	2.011021	0.327267	4.120844	-0.74814	-1.87516	1.698193	2.26008	-2.85803	-3.93627
16	-1.12697	-3.84578	-2.30122	-1.87958	-10.5168	-12.2051	-8.81413	-6.77474	-6.1909	-1.91821
17	-3.76633	-9.40713	-16.8451	-4.61423	0.984343	-3.15524	-11.1776	-8.7656	0.265855	3.396696
18	1.195362	3.161216	1.161803	-2.03256	-1.16988	-3.77296	-3.91218	-2.84116	-0.13808	-2.20171
19	4.782801	-0.90352	0.197847	-16.1555	-20.9943	-7.41238	-9.86593	-6.72001	2.994191	-2.21222
20	2.522926	4.799685	1.590019	-4.44658	-1.35412	3.179039	1.902885	-4.48466	-6.92886	-7.22466

* Odd sample was excluded for the normal distribution of the data.

Appendix C.46 19 participants' self-reported rating scores to the Fabric 7 and Fabric 8 on the Valence, Arousal and Likert scales.

Participant	Rating Scores on Valence Scale to Fabric 7	Rating Scores on Valence Scale to Fabric 8	Difference of Rating Scores on Valence Scale	Rating Scores on Arousal Scale to Fabric 7	Rating Scores on Arousal Scale to Fabric 8	Difference of Rating Scores on Arousal Scale	Rating Scores on Likert Scale to Fabric 7	Rating Scores on Likert Scale to Fabric 8	Difference of Rating Scores on Likert Scale
1	-2	0	-2	-2	0	-2	-1	0	-1
2	4	0	4	-4	0	-4	3	0	3
3	0	2	-2	-1	1	-2	1	2	-1
4	2	-3	5	1	-2	3	3	-1	4
5	-4	0	-4	0	1	-1	-4	0	-4
6	2	3	-1	2	3	-1	0	3	-3
7	-1	1	-2	0	0	0	-1	1	-2
8	-3	-1	-2	-2	0	-2	-1	2	-3
9	1	2	-1	0	1	-1	0	1	-1
10	1	4	-3	-1	3	-4	1	4	-3
11	0	0	0	-1	-2	1	-1	-1	0
12	0	0	0	0	3	-3	-2	1	-3
13	0	2	-2	-1	2	-3	0	1	-1
14	0	-4	4	0	-3	3	0	-4	4
15	-3	-3	0	-3	-1	-2	-2	-4	2
16	4	1	3	2	0	2	3	-1	4
17	-1	2	-3	-3	1	-4	-2	2	-4
18	2	2	0	2	2	0	1	2	-1
19	1	2	-1	-2	1	-3	2	2	0

Appendix C.47 A self-written script of Presentation scenario for presenting the slides in the event-related potential experiment.

```
#header
scenario = "1s fabric viewing";
default_background_color = 128, 128, 128;
write_codes=true;
pulse_width=20; # default pulse width =5ms


begin;


#SDL


trial {
  trial_duration = 8000;
  picture {
    text {caption = "Preparing..."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Preparation";
}preparation_trial;     # Preparation screen with a white "Preparing..." at the center


trial {
  trial_duration = 10000;
  picture {
    text {caption = "Eyes Close"; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "EyesClose";
}eyesclose_trial;     # screen with a white "Eyes Close" at the center


trial {
```

```
  trial_duration = 3000;
  picture {
    text {caption = "Eyes Open"; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "EyesOpen";
}eyesopen_trial;      # screen with a white "Eyes Open" at the center

trial {
  trial_duration = 4000;
  picture {
    text {caption = "Blink Eyes."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Blink";
}blink_trial;      # Blink screen with a white "Blink Eyes Once." at the center

trial {
  trial_duration = 500;
  picture {
    text {caption = " "; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "BlinkInterval";
}blinkinterval_trial;      # Blink Interval screen after blink eyes with a grey screen display



trial {
```

```
  picture {
    text {caption = " "; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Interval";
}interval_trial;     # Interval screen with a grey screen display

trial {
  trial_duration = 20000;
  picture {
    text {caption = "20 Seconds Break."; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "Break";
}break_trial;     # Break screen with a white "20 Seconds Break." at the center

trial {
  trial_duration = 3000;
  picture {
    text {caption = "Section End"; font_size = 30; font_color = 255, 255, 255;
    };
    x = 0; y = 0;
  };
  port_code=2;
  code = "End";
}end_trial;     # screen with a white "Section End" at the center

array {
  bitmap {filename = "1.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric1";}fabric1;
  bitmap {filename = "2.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric2";};
  bitmap {filename = "3.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric3";};
```

```
  bitmap {filename = "4.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric4";};
  bitmap {filename = "5.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric5";};
  bitmap {filename = "6.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric6";};
  bitmap {filename = "7.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric7";};
  bitmap {filename = "8.jpg"; width = 1040; scale_factor = scale_to_width; description = "fabric8";};
}fabrics;

trial {
    stimulus_event {
        picture { bitmap fabric1; x = 0; y = 0;
                } pic;
        duration = 1000;
        port_code=1;
        }event1;
}main_trial;

begin_pcl;

#pcl
preparation_trial.present();

loop int i = 1 until i > 5 begin
  eyesclose_trial.present();
  eyesopen_trial.present();

    loop int j = 1 until j > 2 begin
      fabrics.shuffle();

      blink_trial.present();
      blinkinterval_trial.present();
      loop int k = 1 until k > 4 begin
        interval_trial.set_duration(random(500,1000));
        interval_trial.present();
        pic.set_part( 1, fabrics[k] );
        event1.set_event_code( fabrics[k].description() );
```

```
        main_trial.present();
       k = k + 1
      end;

      blink_trial.present();
      blinkinterval_trial.present();
      loop int k = 5 until k > 8 begin
        interval_trial.set_duration(random(500,1000));
        interval_trial.present();
        pic.set_part( 1, fabrics[k] );
        event1.set_event_code( fabrics[k].description() );
        main_trial.present();
       k = k + 1
      end;
    j = j + 1
    end;

 i = i + 1
end;

break_trial.present();

loop int i = 1 until i > 5 begin
  eyesclose_trial.present();
  eyesopen_trial.present();

    loop int j = 1 until j > 2 begin
      fabrics.shuffle();

      blink_trial.present();
      blinkinterval_trial.present();
      loop int k = 1 until k > 4 begin
        interval_trial.set_duration(random(500,1000));
        interval_trial.present();
        pic.set_part( 1, fabrics[k] );
```

```
        event1.set_event_code( fabrics[k].description() );
        main_trial.present();
       k = k + 1
      end;

      blink_trial.present();
      blinkinterval_trial.present();
      loop int k = 5 until k > 8 begin
        interval_trial.set_duration(random(500,1000));
        interval_trial.present();
        pic.set_part( 1, fabrics[k] );
        event1.set_event_code( fabrics[k].description() );
        main_trial.present();
       k = k + 1
      end;
    j = j + 1
    end;

 i = i + 1
end;

break_trial.present();

loop int i = 1 until i > 5 begin
  eyesclose_trial.present();
  eyesopen_trial.present();

    loop int j = 1 until j > 2 begin
      fabrics.shuffle();

      blink_trial.present();
      blinkinterval_trial.present();
      loop int k = 1 until k > 4 begin
        interval_trial.set_duration(random(500,1000));
        interval_trial.present();
```

```
        pic.set_part( 1, fabrics[k] );

        event1.set_event_code( fabrics[k].description() );

        main_trial.present();

       k = k + 1

      end;


      blink_trial.present();

      blinkinterval_trial.present();

      loop int k = 5 until k > 8 begin

        interval_trial.set_duration(random(500,1000));

        interval_trial.present();

        pic.set_part( 1, fabrics[k] );

        event1.set_event_code( fabrics[k].description() );

        main_trial.present();

       k = k + 1

      end;

    j = j + 1

    end;


 i = i + 1

end;


end_trial.present();
```

Appendix C.48 A self-written script performing in MATLAB for detecting the local amplitude and latency of ERP component P1.

```
c = 1;
for D = {Ch8Con1,Ch8Con2,Ch5Con1,Ch5Con2}
 for x = 1:20
 DATA1 = D{1,1}(x,1:40);
 [pks1,locs1]= findpeaks((double(DATA1)));
 P1Amplitude(x,c) = max(pks1);
 p = single(pks1);
  for m = 1:length(p)
      if p (1,m) == P1Amplitude(x,c);
         P1Latency(x,c) = locs1(1,m)*5;
      end;
   end;
 end;
c = c+1;
end
```

Appendix C.49 A self-written script performing in MATLAB for detecting the local amplitude and latency of ERP component N1.

```
c = 1;
for D = {Ch8Con1,Ch8Con2,Ch5Con1,Ch5Con2}
for x = 1:20
 DATA2 = D{1,1}(x,1:50)*-1;
 [pks2,locs2]= findpeaks((double(DATA2)));
 N1Amplitude(x,c) = max(pks2)*-1;
 n = single(pks2);
  for m = 1:length(pks2)
      if n(1,m)== N1Amplitude(x,c)*-1;
         N1Latency(x,c) = locs2(1,m)*5;
      end;
  end;
end
c = c+1;
end
```

Appendix C.50 A self-written script performing in MATLAB for detecting the local amplitude and latency of ERP component P2.

```
c = 1;
for D = {Ch8Con1,Ch8Con2,Ch5Con1,Ch5Con2}
 for x = 1:20
 DATA1 = D{1,1}(x,1:60);
 [pks1,locs1]= findpeaks((double(DATA1)));
 P2Amplitude(x,c) = max(pks1);
 p = single(pks1);
 for m = 1:length(p)
      if p (1,m) == P2Amplitude(x,c);
         P2Latency(x,c) = locs1(1,m)*5;
      end;
  end;
 end;
c = c+1;
end
```

Appendix C.51 Differences of 20 participants' local peak amplitudes and latencies of component P1, N1 and P2 in the location O1 when responding to Fabric 1 and Fabric 2.

P1Amplitude (μv)	P1Latency (ms)	N1Amplitude (μv)	N1Latency (ms)	P2Amplitude (μv)	P2Latency (ms)
-3.99758	5	-1.8236	15	0.941006	-31
3.296495	40	3.209828	20	3.557822	-5
3.991982	-20	3.518507	-10	-2.65831	-25
-1.796	0	0.426014	0	1.816066	0
-0.73886	20	3.686764	0	-0.55138	-5
4.186	0	3.063393	0	0.354381	0
0.171849	0	-0.1005	10	-3.95711	-10
-0.61283	-10	-0.91403	-10	0.182714	-5
3.464	-20	0.077016	5	2.782092	-5
0.434	-10	-0.06471	5	0.298887	-15
0.18516	-15	-1.32837	10	-0.10017	-15
-0.24765	5	-2.10071	0	2.297862	-20
0.864	-10	2.2108	5	1.19151	45
-5.32665	-10	0.359589	-5	-2.35151	10
1.967879	-15	-3.22388	5	-2.10413	-15
-0.005	15	-1.51946	30	0.304237	30
-0.6397	15	0.544944	0	-3.49276	0
-0.7348	5	0.358659	15	1.317	0
5.141292	-15	-1.15601	-5	0.836473	-25
8.331085	10	5.357826	0	-0.31315	0

Appendix C.52 Differences of 20 participants' local peak amplitudes and latencies of component P1, N1 and P2 in the location O2 when responding to Fabric 1 and Fabric 2.

P1Amplitude (μv)	P1Latency (ms)	N1Amplitude (μv)	N1Latency (ms)	P2Amplitude (μv)	P2Latency (ms)
-4.92021	5	-0.74982	15	-0.26186	-15
-0.03459	-5	4.525209	-20	4.918421	0
1.604142	-10	2.916954	10	-2.09756	0
-1.079	0	1.198076	0	0.149963	0
0.008	10	3.680802	0	1.667918	0
-2.83012	-10	3.047333	-15	2.053135	15
0.713226	5	-0.16153	-5	-3.62019	5
-1.5754	15	-2.23387	10	-1.07323	-5
3.0498	-20	4.143928	-5	3.838653	0
1.182	-10	1.207372	5	1.342193	-15
0.6965	-5	-1.75688	-10	-0.85751	-15
-1.81577	5	-5.1105	0	-0.30909	-20
0.882	-5	1.268377	-15	4.0699	-15
-3.06447	15	-1.3561	10	-0.87886	-25
0.195128	25	0.147885	5	1.203067	-15
1.779641	-5	0.208238	-10	1.460215	-10
0.15734	0	2.498698	0	-0.65915	-5
0.880181	-10	1.943842	15	0.864	-20
4.552	0	0.362038	-5	2.083671	-45
8.435503	5	4.68294	-5	-0.84521	-5

Appendix C.53 Differences of 20 participants' amplitudes calculated by the second measuring method of component N1 and P2 in the O1, O2 channels when responding to the Fabric 1 and Fabric 2.

O1 electrode channel		O2 electrode channel	
N1 Amplitude (μv)	P2 Amplitude (μv)	N1 Amplitude (μv)	P2 Amplitude (μv)
-2.17398	2.764608	-4.17038	0.487963
0.086667	0.347994	-4.55979	0.393212
0.473474	-6.17681	-1.31281	-5.01452
-2.22201	1.390051	-2.27708	-1.04811
-4.42562	-4.23814	-3.6728	-2.01288
-6.05902	-2.70901	-5.87746	-0.9942
0.272348	-3.85662	0.874759	-3.45866
0.301202	1.096745	0.658468	1.160635
3.386984	2.705076	-1.09413	-0.30528
0.49871	0.363597	-0.02537	0.134821
1.513535	1.228204	2.453378	0.899371
1.853061	4.398568	3.294726	4.80141
-1.3468	-1.01929	-0.38638	2.801532
-5.68624	-2.7111	-1.70837	0.477237
5.191759	1.119747	0.047244	1.055182
1.514458	1.823695	1.571403	1.251977
-1.18464	-4.0377	-2.34136	-3.15785
-1.09346	0.958341	-1.06366	-1.07984
6.297299	1.992481	-1.67637	1.721632
2.973259	-5.67097	3.752563	-5.52815

Appendix C.54 Differences of 20 participants' local peak amplitudes and latencies of component P1, N1 and P2 in the location O1 when responding to Fabric 3 and Fabric 4.

P1Amplitude (µv)	P1Latency (ms)	N1Amplitude (µv)	N1Latency (ms)	P2Amplitude (µv)	P2Latency (ms)
-2.12064	10	2.75822	-10	0.43607	-10
-3.60900	-45	-1.21349	10	-2.86558	15
1.58948	30	4.88355	-10	4.68909	5
-1.05400	5	-0.84488	-5	0.38630	5
-1.43126	-5	0.29279	-5	-2.39549	-15
-2.62779	20	2.14002	-20	-0.01661	-20
-1.47561	5	2.82137	0	0.80083	30
-0.13234	-20	1.39744	10	0.27805	-15
0.78000	30	1.64252	-15	2.20611	45
-3.18709	-15	-2.39635	-15	-0.91074	-35
0.57859	10	-2.01903	-5	-3.14244	-40
0.15187	0	0.15364	0	0.99187	-20
-6.52035	-15	0.93829	0	0.73655	5
3.51400	15	-1.06060	-20	5.46844	15
1.85215	-15	-1.53300	*	2.16504	-30
3.63920	0	-2.24184	0	6.03866	0
-4.33694	25	6.80761	5	3.94653	-10
-3.75303	15	-2.63488	0	-2.32100	30
0.74100	0	-0.98791	10	-1.91124	-15
-0.69636	0	-0.33279	0	-1.94300	-5

Appendix C.55 Differences of 20 participants' local peak amplitudes and latencies of component P1, N1 and P2 in the location O2 when responding to Fabric 3 and Fabric 4.

P1Amplitude (μv)	P1Latency (ms)	N1Amplitude (μv)	N1Latency (ms)	P2Amplitude (μv)	P2Latency (ms)
-2.22898	10	4.50278	10	-0.68689	-30
-3.23400	15	-3.92288	-5	-3.07431	15
0.96786	15	4.08257	0	3.05096	0
-0.49300	5	-0.19435	0	0.16249	10
-3.07100	-5	0.65763	-5	-3.18200	10
-1.20400	0	2.49124	-20	0.61964	0
-2.22011	10	3.33661	10	0.96606	-30
1.67532	-25	1.71782	10	0.13016	20
2.58700	0	0.81596	5	0.83902	-15
-3.53850	-10	-0.46728	-15	0.37497	-35
0.99339	-5	-0.99596	-35	-3.13858	-35
-0.67200	0	-1.14213	-5	1.41656	0
-6.02699	-20	-0.95175	5	-0.05337	-15
3.35200	0	2.22980	0	4.15798	15
4.22900	-5	0.93484	15	8.42840	10
3.16490	-20	-3.49712	-20	2.81512	5
-0.63426	10	3.15349	25	1.80142	-10
-2.77411	15	-1.15510	0	-0.05300	30
-0.27300	0	-0.93441	10	-2.40457	-15
-2.24214	-10	-0.82906	-40	-4.72700	-20

Appendix C.56 Differences of 20 participants' amplitudes calculated by the second measuring method of component N1 and P2 in the O1, O2 channels when responding to the Fabric 3 and Fabric 4.

O1 electrode channel		O2 electrode channel	
N1 Amplitude (μv)	P2 Amplitude (μv)	N1 Amplitude (μv)	P2 Amplitude (μv)
-4.8789	-3.19429	-6.73176	-5.18967
-2.3955	-1.65208	0.68888	0.84858
-3.2941	-0.19446	-3.11472	-1.03161
-0.2091	1.23117	-0.29865	0.35684
-1.7240	-2.68828	-3.72863	-3.83963
-4.7678	-2.15663	-3.69524	-1.87160
-4.2970	-2.02054	-5.55672	-2.37055
-1.5298	-1.11939	-0.04250	-1.58766
-0.8625	0.56359	1.77104	0.02307
-0.7907	1.48561	-3.07122	0.84226
2.5976	-1.12341	1.98935	-2.14261
-0.0018	0.83822	0.47013	2.55869
-7.4586	-0.20173	-5.07524	0.89838
4.5746	*	1.12220	1.92818
3.3852	3.69804	3.29416	7.49356
5.8810	*	6.66202	6.31224
-11.1446	-2.86109	-3.78775	-1.35208
-1.1181	0.31388	-1.61901	1.10210
1.7289	-0.92332	0.66141	-1.47016
-0.3636	-1.61021	-1.41308	-3.89794

Appendix C.57 Differences of 20 participants' local peak amplitudes and latencies of component P1, N1 and P2 in the location O1 when responding to Fabric 5 and Fabric 6.

P1Amplitude (μv)	P1Latency (ms)	N1Amplitude (μv)	N1Latency (ms)	P2Amplitude (μv)	P2Latency (ms)
4.75692	0	-0.73675	-25	-1.00092	-20
-2.25252	0	1.23700	25	-0.32035	-15
-0.91316	10	-0.22741	5	1.18838	20
2.00851	-15	3.53663	5	0.89668	-15
0.71383	-20	1.36008	-30	-0.93008	0
4.46788	0	8.41365	0	0.96719	45
0.50043	-10	3.91026	-5	-4.67610	0
-0.11991	10	5.93444	10	-0.21533	-20
1.75400	15	2.98795	5	2.76984	0
-0.48584	-10	-1.36870	10	-0.08006	-10
1.62905	45	1.61521	-10	0.47347	5
0.33200	15	3.70240	-15	2.47187	10
0.69559	-20	-0.60903	0	-3.16974	-5
-5.13230	-15	0.15900	-30	0.62880	-25
0.81306	-5	4.39944	20	-3.32407	0
-2.59823	40	2.13258	5	-2.46958	-20
-2.23700	0	0.47162	5	-5.10557	-20
-0.31703	10	-1.00552	-5	-2.83000	0
2.15900	15	1.03750	20	-0.17124	-30
-4.72031	10	5.91839	-15	-2.70700	-15

Appendix C.58 Differences of 20 participants' local peak amplitudes and latencies of component P1, N1 and P2 in the location O2 when responding to Fabric 5 and Fabric 6.

P1Amplitude (μv)	P1Latency (ms)	N1Amplitude (μv)	N1Latency (ms)	P2Amplitude (μv)	P2Latency (ms)
4.43774	5	-1.39418	-20	-0.03747	0
-0.20998	5	1.27999	25	-1.11374	-15
0.35556	5	0.11100	5	2.08455	10
1.69100	-15	3.98470	5	-0.56092	-15
-1.68002	-15	-1.23153	5	-4.50028	-5
1.14785	25	6.53759	-15	0.37771	-15
-2.15617	0	0.69720	-5	-6.14821	10
-0.30654	5	5.88590	10	-0.75091	-5
5.20970	15	3.49938	30	4.94848	-25
-0.39402	-10	-0.76037	10	-0.65900	-10
-0.11593	40	2.51826	-35	0.65477	-10
0.22860	15	4.53614	-5	3.47030	5
-1.16890	0	-0.37447	0	-3.58410	-5
-2.84266	-15	2.56700	-5	2.89380	-5
0.63879	-40	4.07154	20	-0.61125	-20
-0.68800	5	1.62385	0	-2.24268	-5
-2.68300	0	-0.62250	20	-6.47207	-15
2.45665	5	2.30554	-5	-0.16100	5
0.18873	-5	3.00660	10	0.63337	-30
-6.84082	5	5.78355	-15	-3.05300	-5

Appendix C.59 Differences of 20 participants' amplitudes calculated by the second measuring method of component N1 and P2 in the O1, O2 channels when responding to the Fabric 5 and Fabric 6.

O1 electrode channel		O2 electrode channel	
N1 Amplitude (μv)	P2 Amplitude (μv)	N1 Amplitude (μv)	P2 Amplitude (μv)
5.4937	-0.26417	5.8319	1.35672
-3.4895	-1.55735	-1.4900	-2.39373
-0.6858	1.41579	0.2446	1.97355
-1.5281	-2.63994	-2.2937	-4.54562
-0.6463	-2.29016	-0.4485	-3.26875
-3.9458	-7.44646	-5.3897	-6.15988
-3.4098	-8.58636	-2.8534	-6.84542
-6.0544	-6.14977	-6.1924	-6.63681
-1.2339	-0.21811	1.7103	1.44910
0.8829	1.28864	0.3663	0.10137
0.0138	-1.14175	-2.6342	-1.86349
-3.3704	-1.23053	-4.3075	-1.06584
1.3046	-2.56071	-0.7944	-3.20963
-5.2913	0.46980	-5.4097	0.32680
-3.5864	-7.72352	-3.4328	-4.68279
-4.7308	-4.60216	-2.3118	-3.86653
-2.7086	-5.57720	-2.0605	-5.84957
0.6885	-1.82448	0.1511	-2.46654
1.1215	-1.20874	-2.8179	-2.37323
-10.6387	-8.62539	-12.6244	-8.83655

Appendix C.60 Differences of 20 participants' local peak amplitudes and latencies of component P1, N1 and P2 in the location O1 when responding to Fabric 7 and Fabric 8.

P1Amplitude (µv)	P1Latency (ms)	N1Amplitude (µv)	N1Latency (ms)	P2Amplitude (µv)	P2Latency (ms)
4.19873	-10	3.00990	15	5.71500	10
-0.29227	5	1.26960	25	-5.01888	-15
3.11321	-40	-1.36860	-5	-4.22481	-5
-0.49400	-10	-1.15064	-5	-3.58392	10
0.54800	-5	1.74627	15	0.23884	0
-4.94178	-10	-3.27129	5	-4.49054	5
3.44571	5	-1.39996	0	-3.84824	-10
0.08500	5	2.76560	0	-0.44123	20
*	*	*	*	0.70090	20
0.19400	0	-1.15227	0	-1.48758	0
*	*	-0.42597	40	-0.87600	0
-1.11573	-10	0.86757	-5	-0.54220	-5
5.59254	25	1.41329	10	*	*
-0.29700	-30	*	*	-1.66860	10
-3.38101	5	4.68480	45	-3.75846	-10
-0.24000	-35	-1.04257	-25	1.83349	25
0.38510	-25	7.30775	10	3.22729	20
-1.88738	-10	1.65095	15	-0.89000	5
0.81286	-10	-3.07600	20	-6.86821	5
2.58250	5	-2.15699	25	0.39000	-10

Appendix C.61 Differences of 20 participants' local peak amplitudes and latencies of component P1, N1 and P2 in the location O2 when responding to Fabric 7 and Fabric 8.

P1Amplitude (μv)	P1Latency (ms)	N1Amplitude (μv)	N1Latency (ms)	P2Amplitude (μv)	P2Latency (ms)
4.24601	10	1.70973	0	4.12500	-50
2.18857	-15	-1.46700	-15	-4.55437	-15
-0.32694	-35	-3.23211	-5	-5.18212	0
-2.07900	-5	-0.48775	30	-2.42000	10
0.16422	0	1.97352	10	1.23370	20
-6.55435	5	-4.45255	-5	-3.19299	5
2.05137	15	0.77587	15	-3.69253	-10
-1.60611	30	2.67947	5	-0.16875	25
-1.66400	-5	-4.42862	-10	3.33959	-10
-0.37300	5	-1.48262	0	-2.51552	0
-0.52460	-5	-0.70722	-15	-0.82100	0
-3.85405	15	-0.06367	-5	-1.40000	-5
5.24424	25	1.68212	25	-3.14671	-50
-0.12247	-20	-2.05590	-5	-1.01751	-10
-3.78390	40	5.39064	40	-4.37002	-15
0.02321	5	1.45090	20	2.08798	25
0.05100	0	4.17512	-5	2.66405	0
0.56672	-10	0.86802	10	0.94700	15
1.49112	5	-2.88308	10	-7.39085	-15
3.49180	10	-0.76565	10	0.42352	-15

Appendix C.62 Differences of 20 participants' amplitudes calculated by the second measuring method of component N1 and P2 in the O1, O2 channels when responding to the Fabric 7 and Fabric 8.

O1 electrode channel		O2 electrode channel	
N1 Amplitude (μv)	P2 Amplitude (μv)	N1 Amplitude (μv)	P2 Amplitude (μv)
-6.0894	2.70510	2.53628	2.41527
-13.5487	-6.28848	3.65557	-3.08737
-1.6119	-2.85621	2.90517	-1.95001
-8.9401	-2.43328	-1.59125	-1.93225
-10.0557	-1.50743	-1.80930	-0.73982
-21.7794	-1.21925	-2.10180	1.25956
-11.6176	-2.44828	1.27550	-4.46840
-10.1110	-3.20682	-4.28558	-2.84822
*	*	2.76462	7.76821
-7.8293	-0.33532	1.10962	-1.03291
*	-0.45003	0.18262	-0.11378
-17.2882	-1.40977	-3.79038	-1.33633
-9.1644	*	3.56211	-4.82884
*	*	1.93343	1.03839
-16.4958	-8.44326	-9.17454	-9.76066
-3.5680	2.87606	-1.42769	0.63708
-17.0569	-4.08046	-4.12412	-1.51107
-17.9297	-2.54095	-0.30130	0.07898
-2.9521	-3.79221	4.37421	-4.50776
-16.6005	2.54699	4.25744	1.18917

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